(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
19 August 2004 (19.08.2004)

PCT

(10) International Publication Number
WO 2004/069508 A2

(51) International Patent Classification[7]: B29C

(21) International Application Number: PCT/EP2004/000855

(22) International Filing Date: 1 February 2004 (01.02.2004)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
MI2003A000177 4 February 2003 (04.02.2003) IT

(71) Applicant (*for all designated States except US*): **FIN-TRADE S.R.L** [IT/IT]; 60, Via Mazzini, I-25020 Alfianello (IT).

(72) Inventor; and
(75) Inventor/Applicant (*for US only*): **JULITA, Francesca** [IT/IT]; 24, Via Lungo Lario Cadorna, I-22053 Lecco (IT).

(74) Agent: **FERRAIOLO, Ruggero**; Via Napo Torriani, 10, I-20124 Milano (IT).

(81) Designated States (*unless otherwise indicated, for every kind of national protection available*): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

(84) Designated States (*unless otherwise indicated, for every kind of regional protection available*): ARIPO (BW, GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

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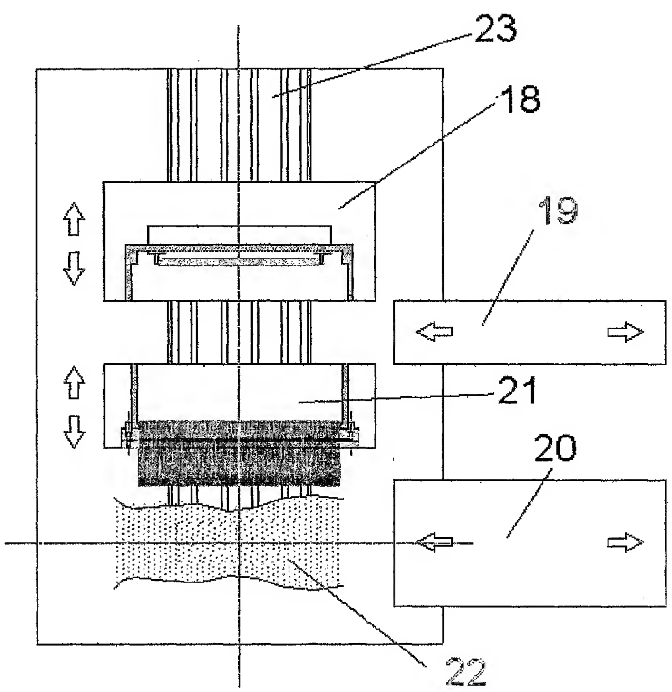
(54) Title: SYSTEM FOR THERMOFORMING, DIGITALIZING AND REPRODUCING THE EXTERNAL SURFACE OF AN OBJECT IN THREE-DIMENSIONS, VIRTUALLY AND/OR IN THERMOFORMABLE PLASTIC MATERIAL



(57) Abstract: Modular devices are capable of thermoforming external surfaces of objects (22) from panels of thermoformable plastic materials; carrying out three-dimensional scannings of pre-existing objects taken as model, translating them into external surfaces of virtual objects capable of being processed by means of CAD programs; carrying out remote reproduction operations of the previously digitalized surfaces or of surfaces of obtained from CAD data conserved in a database, in the form of objects thermoformed in plastic material; more generally, the system is capable of producing from a panel of thermoformable plastic material the copy of the external surface of any object whatsoever or of translating the external surface of any object whatsoever into the virtual external surface of the same object and thermoforming, even remotely, the geometry of the external surface of a virtual object into a plastic external surface.

WO 2004/069508 A2

Declaration under Rule 4.17:

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Published:

— *without international search report and to be republished upon receipt of that report*

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System for thermoforming, digitalizing and reproducing the external surface of an object in three-dimensions, virtually and/or in thermoformable plastic material

The present invention relates to a system for thermoforming, digitalizing and reproducing the external surface of objects in three dimensions substantially developed as bas-reliefs and/or in the round from a panel of thermoformable plastic material, and in particular a modular photo-optical system for ascertaining, by means of a scanning and digitalization action, and transmitting to a personal computer (hereinafter referred to more simply as PC) the external surface of a pre-existing object taken as model and translating it into the virtual external surface of the object represented in three dimensions (three dimensions that hereinafter will be referred to more simply as 3D), capable of being processed on a PC monitor by means of any CAD program in common use, and thermoforming, also remotely, by means of a transmission and reproduction action, the external surface in thermoformable plastic material of a pre-existing object taken as model that has been digitalized to be transmitted to another place or the external surface of a data-base-conserved virtual object designed with a CAD system.

Prior art

In general, the prior art relating to the moulding of thermoformable plastic material in panel form comprises moulding by vacuum forming, high pressure forming, mechanical forming, so-called pressure diaphragm forming and twin sheet forming. It also comprises the hot-moulding device claimed in the Italian patent application No. MI2001A001345 of 27 June 2001, in which a mobile structure comprises a needle matrix where a plurality of needles can slide when the matrix is pressed against an

object/model, so that the upper ends of the needles become arranged in accordance with the external surface of the object/model, a panel of thermoplastic material placed on top of the needles assumes the shape of said external surface with the help of pressurized gas injected above the panel and a source of heat that supplies the heat necessary for the thermoforming. This device will be described in detail also in the present description.

The prior art relating to the transformation of the external surface of a pre-existing model object surveyed and digitalized into the external surface of a virtual 3D object comprises principally the use of lasers, feelers, video cameras and video projectors.

The prior art relating to the realization of an object in plastic material or in other material by means of data obtained from a CAD work preserved in a database comprises principally the use of lasers and milling cutters and the use of stereolithography (SLA); and such methods as LOM, FDM, 3DP and SGC.

In particular, the prior art for hot moulding of the external surface of an object from a panel of thermoformable plastic material (panel is here intended as referring also to a very thin element like a sheet of thermoplastic or thermo-hardening material) calls for a mould of the pre-existing object taken as model if the object itself, due to its nature or composition, cannot be used as pattern for the thermoforming in a direct manner, or calls for the realization of the corresponding negative mould (pattern) of the external surface of the object to be reproduced and calls for the working and modelling by sculpturing of the external surface (or its being turned into a prototype and the consequent realization of the positive mould) for a pre-existing object taken as model digitalized and transmitted in another place in the form of informatics data or for an virtual object designed with a CAD design program conserved in a database.

The disadvantages of the prior art consist of the limited use that is being made of 3D scanners due to their cost; the need for constructing a negative pattern (mould) for the production of outline copies of a pre-existing object taken as model when the object itself cannot be used as direct model for the thermoforming and the fabrication of a positive pattern/mould (prototype) for the realization of the first plastic external surface of a virtual object (designed and obtained from CAD data conserved in a database or from informatics data obtained from the external surface of a pre-existing model object digitalized into a virtual external surface) to be transmitted and physically reproduced also in another place.

Description of the invention

The system in accordance with the present invention is a photo-optical electronic system consisting of a plurality of devices each comprised in a module interacting with the others, as will be specified further on, and between them capable of thermoforming the external surface of objects from panels of thermoworkable plastic materials without the help of positive or negative moulds; of carrying out 3D scannings of the external surface of pre-existing objects taken as model and translating them into virtual surfaces that can be worked (processed) with CAD programs in common use; of carrying out remote reproduction operations by means of 3D fax of said external surface previously digitalized and/or obtained from a design made with a CAD program and conserved in a database in the form of an external surface moulded from thermoformable plastic material.

More generally, the system is capable of reproducing from a panel of thermoformable plastic material the copy of the external surface of any object and/or the external surface of a digitalized object and/or obtained from a design made with a CAD program and conserved in a database, the latter transmitted either locally or

remotely by means of a network, and translating the external surface of any object into the virtual three-dimensional external surface of that same object.

The invented system comprises devices realized for the purpose of integrating all the operations describe above and making it possible to perform these operations also selectively. The modularity of the devices is the characteristic of the system that renders the chosen and utilized devices of the electronic photo-optical system capable of being interfaced with each other. The junction interface between modules makes it possible to combine the modules for the purpose of obtaining the various operations required, the interfacing being made possible, in particular, by the coupling means arranged at the external edges of the modules. The modules interact interfaced and work together inserted in housings that constitute the ordered and serial configuration chosen according to the thermoforming, scanning or fax reproduction use to which the module system is to be put, bringing about the coupling and union of the chosen modules into a standardized configuration. All the modules of the composite electronic photo-optical device are capable of translating and rotating relative to each other in order to permit their being combined for use, brought side by side, united and correctly positioned with respect to the object that is to be thermoformed, digitalized and reproduced (hereinafter referred to as object obj).

Table 1 below sets out and describes the symbols used in the present text.

Table 1

Symbol	Description
obj	Object
La	Needle length
ds	Needle density
da	Needle diameter

A	Dimension along x-axis [mm]
B	Dimension along y-axis [mm]
PL	Scanning plane of the plate
Sp	Thickness of the plate PL [mm]
x	x-axis of Cartesian reference system
y	y-axis of Cartesian reference system
z	z-axis of Cartesian reference system
nst	Step, distance z
px	Image pixels along x-direction
py	Image pixels along y-direction
ppx	A [mm] / px
ppy	B [mm] / py
W/B	White / Black
Ax	x-axis of module VT-MF: movement along x direction
Ay	y-axis of module VT-MF: movement along y direction
Az	z-axis of module VT-MF: movement along z direction
P_i	Generic point of the coordinate surface $(x, y, z)_i$
BW	Typical matrix (m, n) of W/B image data (0, 1)
m	= px
n	= py
DM	Typical matrix of the dimensional steps [m, n]
nz	Index indicating the number of scannings or the number of acquired images
pnz	z [mm] / nz

C	Summation of the (m, n)-type data matrices BW from 1 to nz
Cr	C * pnz matrices of type (m, n)
3D	Numerical matrix representing the external surface of the object
$(A, B)_i$	Needle matrices with different dimensional formats A and B
T	Total film shooting time
t	Generic shooting instant
nf	= [images/s]
Vz	= [mm/s]
N image	Number of images = t * nf
S image	Displacement associated with the image N image = t * Vz

This electronic photo-optical system for thermoforming, digitalizing and reproducing in three dimensions the external surface of an object, either virtually or in thermoformable plastic material, using a needle matrix (VT-MM) that surveys the external surface of the object, is characterized in that it comprises:

- an integrated module for the mathematical calculation and management of the informatics data (VT-Data);
- a needle matrix module (VT-MM);
- a high-precision matrix module (VT-MP);
- a scanner module (VT-MS);
- a module for reproduction by means of fax (VT-MF);
- a module for the thermoforming (VT-MT).

capable of performing the following actions:

(1) surveying (ascertaining), by means of a mechanical needle matrix system, the external surface of an object obj and obtaining its mapping in terms of

levels referred to a predetermined reference plane;

(2) hot moulding from a panel of thermoformable plastic material of suitable formulation the external surface of a pre-existing object obj taken as model and/or obtained from informatics data;

(3) processing and reproducing the mathematics that describe the geometries of the external surface of a pre-existing object obj taken as model by means of the survey referred to in (1) above;

(4) transferring into the database of a processor the mathematical data acquired by means of the digitalization of the external surface of a pre-existing object obj taken as model for the purpose of reproducing in a PC the external surface of said surveyed object obj represented in the form of a virtual external surface that can be processed by means of CAD systems in common use;

(5) transferring the mathematical data, by means of a local and/or a remote network, for the purpose of realizing, in thermoplastic material of appropriate formulation, the identical surface of the object obj surveyed and digitalized by means of the mechanical needle matrix system (items 1 and 3 above), physically providing one or more reproductions on a panel (item 2 above), and/or thermoforming the external surface of a virtual object obj obtained from CAD data conserved in a database.

Given its capacity of being operated as a modular electronic device, the advantage of the invention consists of its eliminating the need for constructing a negative mould for an object obj taken as model in order to be able to thermoform the external surface of said object obj into a thermoformed plastic object obj whenever this object, by its nature and consistency, is not capable of being used as a direct pattern for the thermoforming (for example, a hand or a foot pressed against the needles of the module VT-MM), thus permitting the realization of several specimens said external

surface of the object obj; and of its eliminating the need for constructing either a positive or a negative mould of a pre-existing digitalized object obj taken as model that is to be transmitted to and reproduced in another place, or the external surface of a virtual object obj designed by means of a CAD system and conserved in a database, for the realization of the external surface of said virtual object obj (prototype) in thermoformed plastic material.

In 3D scanner modality applied to a photo camera or a video camera in common use, the advantage of the invented electronic photo-optical device as compared with the known technique of 3D laser scanning consists of the smaller cost associated with the device in accordance with the invention.

In 3D fax reproduction modality, the advantage of the invented electronic photo-optical device as compared with the known technique of laser milling and sculpturing of a plastic material corresponding to the virtual object obj conserved in a database consist of the low cost, rapidity and lightness of the plastic copy of the object obj thus obtained, the copy being produced by thermoforming action from a panel of thermoformable material.

The principal application of the invented system is to be found in the following sectors: moulding of thermoformable plastic laminates; production of virtual objects and plastic prototypes in the sector of study and design by means of CAD programs.

Embodiments of the invention

The invention will now be described in greater detail with embodiment examples and with the help of the schemes and drawings attached hereto, of which:

- Figure 1 is a plan view that shows the composition and order of the single-

interface modules,

- Figure 2 is a plan view that shows the composition and order of the double-interface modules,

- Figure 3 is a plan view that shows the interface surfaces and the possible relative translations of the modules;

- Figure 4 contains a vertical view (view from above) and a plan view, partially sectioned, that show the needle matrix module VT-MM,

- Figure 5 is a plan view that shows the needle matrix module VT-MM positioned to ascertain (survey) the external surface of the pre-existing object obj taken as model with the needles blocked, ready for being coupled to the interfaceable modules VT-MT and VT-MS,

- Figure 6 is a first partially sectioned vertical view of the module VT-MM coupled to the thermoforming module VT-MT,

- Figure 7 is a second vertical view of the mobile version of the module VT-MM on an articulated arm,

- Figures 8 and 9 schematically illustrate the functions in the thermoforming phase of the modules VT-MM and VT-MT described with reference to Figures 6 and 7,

- Figures 10 and 11 schematically illustrate the functions of the VT-MS and VT-MM interfaced with each other,

- Figure 12 represents a system of three axes controlled, ordered and commanded by the numerical 3D matrix of the integrated calculation module VT-Data that describes the external surface of a pre-existing object obj taken as model digitalized by means of the module VT-MS or the external surface of a virtual object obj obtained from CAD data,

- Figure 13 represents the three modules VT-MM, VT-MT and VT-MF in a double-interface system, and

- Figure 14 represents the three modules VT-MM, VT-MT and VT-MF in a double-interface system in which VT-MF and VT-MT are shown partially positioned;

- Figure 15 illustrates the acquisition of the data needed by the integrated calculation module VT-Data to generate the numerical 3D matrix and to transfer these acquired data (by means of modem, internal or external network to a remote second electronic photo-optical apparatus).

- Figure 16 schematically illustrates the modules VT-MM and VT-MP.

Figure 17 schematically illustrates the modules VT-MM and VT-MP interfacing with each other.

- Figure 1 is a plan view that shows the composition and order of the single-interface modules. The reference number 18 indicates the module VT-MT, 19 the module VT-MS, 20 the module VT-MF, 21 the module VT-MM, 22 the object <u>obj</u> to be acquired and 23 the guide in which the modules slide; just as in the subsequent figures, the unnumbered white arrows indicate the directions in which the modules can translate.

- Figure 2 is a plan view that shows the composition and order of the double-interface modules. The reference number 18 indicates the module VT-MT, 19 the module VT-MS, 20 the module VT-MF, 21 the module VT-MM, 22 the object <u>obj</u> to be acquired, 23 the guide in which the modules slide and 29 the interface surfaces.

- Figure 3 is a plan view that shows the interface surfaces and the possible relative translations of the modules. The reference number 18 indicates the module VT-MT, 19 the module VT-MS, 20 the module VT-MF, 21 the module VT-MM, 22 the object <u>obj</u> to be acquired, 23 the guide in which the modules slide and 29 the interface

surfaces.

- Figure 4 contains a vertical view (view from above) and a plan view, partially sectioned, that show the needle matrix module VT-MM. The reference number 18 indicates the module VT-MT, 22 the object obj to be acquired, 23 the guide in which the modules slide and 21 again indicates the plan view of the module VT-MM shown on the right of the drawing.

- Figure 5 is a plan view that shows the needle matrix module VT-MM positioned to ascertain (survey) the external surface of the pre-existing object obj taken as model with the needles blocked, ready for being coupled to the interfaceable modules VT-MT and VT-MS. The reference number 18 indicates the module VT-MT, 19 the module VT-MS, 21 the module VT-MM, 22 the object obj to be acquired and 23 the guide in which the modules slide.

- Figure 6 shows the function of the single-matrix thermoforming module, where a first structure 1 that supports a needle-matrix module 2 (VT-MM) comprising a support 3 in which there can slide a plurality of uniformly distributed needles 4, all of equal length, parallel to each other perpendicular to the support, which is of a sufficient height to maintain the needles in their position; a second structure 5, which is a thermoforming module (VT-MT), carries on its underside a chamber 6 in which the lower wall is lacking; this chamber can be lowered until its lower perimetral edge comes to rest on the perimeter of the support 3 and defines the thermoforming chamber 7 between the upper wall, part of the side walls and the panel of thermoformable material 8 that embraces with its perimeter the whole of the plurality of needles 4 lined by a sheath of thermoresistant material 15, the margins of the specific panel being bent over the four sides of the group of needles and clasped between the chamber walls and the lined matrix needles, so that the chamber proves tight to a gas

injected by means of the duct 9 at a pressure suitable for maintaining the panel pressed against the surfaces of the needles for the time necessary for the heat generated in the chamber by the electrical resistance 10 or some other appropriate means to fix the panel in the form it has assumed on the needles; a flat surface 11 on which there rests a model 12 pressed against the lower ends of the needles; the region defined between the upper face of the level surface and the lower ends of the needles defining the modelling area. Within the thickness of the matrix 2 there are accommodated two or more pairs of grids 13 capable of sliding in the direction transverse to the needles and arranged on top of each other, the needles passing through the meshes of the grids, so that a blocking means is provided for the needles when the grids are pulled in opposite directions and maintained in this blocking position by means of pins 14 or some other known means.

- Figure 7 shows the realization of the system as a single-matrix thermoforming system on a mobile arm, wherein the matrix illustrated by Figure 6 is to the end of an articulated arm 13 that is itself fixed to a trestle 14 capable of sliding horizontally in a guide 17 associated with the rear wall of the flat surface 11. The system with its overall structure 1 and the devices 2 to 8 described by Figure 6 is further characterized in that the structure 5 can be made to slide vertically in the direction of the arrow F to lower the chamber 7 onto the support 3 after an operator has transferred the arrangement, by means of the articulated arm, to above the model 12 placed on the flat surface 11 (the arrows F', F", F'" and F^{iv} indicate the movements that can be performed by the various components of the arm), the needles 4, pressed against the upper surface of the model 12, are lifted into the chamber 6 in order to impart the shape of said surface to the panel 8 arranged above the needle lining sheath 15. The function of the electrical resistance or other heating method 10 and the gas

introduced into the chamber 7 by means of the flexible duct 9 has already been described in connection with the previous figure; the reference number 16 indicates a compressor that has the task of sending the gas into the chamber 7 at the desired pressure.

- Figures 8 and 9 illustrate the coupling during the thermoforming phase of the modules VT-MM and VT-MT described in connection with Figures 6 and 7. The reference number 18 indicates the module VT-MT, 21 the module VT-MM, 22 the object obj to be acquired and 23 the guide in which the modules slide

- Figures 10 and 11 illustrate the coupling of the modules VT-MS and VT-MM interfaced with each other. The reference number 19 indicates the module VT-MS, 21 the module VT-MM, 22 e the object obj to be acquired, 23 the guide in which the modules slide, 24 the optical image acquisition surface and 25 the plate PL.

- Figure 12 represents a system of three axes controlled, ordered and commanded by the numerical 3D matrix that describes the external surface of a pre-existing object obj taken as model by the module VT-MS or obtained from CAD data. The reference number 26 indicates the Cartesian axes x, y, z, 30 the rod that slides on the axes x and y, 27 the rod that slides on the axis z and 28 the displacement actuator.

- Figure 13 represents the three modules VT-MM, VT-MT and VT-MF in a double-interface system. The reference number 18 indicates the module VT-MT, 20 the module VT-MF, 21 the module VT-MM and 23 the guide in which the modules slide.

- Figure 14 represents the three modules VT-MM, VT-MT and VT-MF in a double-interface system in which VT-MF and VT-MT are shown positioned. The reference number 18 indicates the module VT-MT, 20 the module VT-MF, 21 the module VT-MM and 23 the guide in which the modules slide.

- Figure 15 illustrates the acquisition of the data needed by the integrated

calculation module VT-Data to generate the numerical 3D matrix and to transfer these acquired data (by means of modem, internal or external network) to a remote second electronic photo-optical apparatus. The reference number 31 indicates the PC in which there resides the hardware and software dedicated to data processing, 32 the complete configuration of the electronic photo-optical system, 33 the system used for remote data transfer (modem, internal or external network) and 34 the cables that connect the PC to the electronic photo-optical system.

Figure 16 schematically illustrates the modules VT-MM and VT-MP. The reference number 21 indicates the module VT-MM, 35 the module VT-MP, 36 the needles of the matrix VT-MP, 22 a small size object obj.

Figure 17 schematically illustrates the modules VT-MM and VT-MP interfacing with each other. The reference number 21 indicates the module VT-MM, 36 the needles of the matrix VT-MP, 35 the module VT-MP in the scanning phase of the 22 object obj to be acquired.

Below we shall now provide detailed descriptions of:

- the integrated module for the mathematical calculation (3D numerical matrix) and the IT management of the input and output data of the system (hereinafter referred to as VT-Data),
- the scanner module (hereinafter referred to as VT-MS),
- the needle matrix module (hereinafter referred to as VT-MM),
  the high-precision matrix module (hereinafter referred to as VT-MP);
- the module for the thermoforming (hereinafter referred to as VT-MT),
- the module for reproduction by means of fax (hereinafter referred to as VT-MF),

(i) Module VT-Data: The module VT-Data is the central heart of the

invented electronic photo-optical system; it:

- acquires
- coordinates
- orders

the modules VT-MM, VT-MP, VT-MS, VT-MT and VT-MF.

Acquisition: The images acquired by the chosen photo-optical surveying system (photo camera or video camera) of the module VT-MS interfaced with the module VT-MM are in standard image format (pixels/square inch), this format is translated into the colours black and white. The black colour is associated with the presence of the needle in the map and the numerical code 1, while the white colour is associated with the non-presence of the needle in the map and the numerical code 0, or vice versa.

The size of the image is known (A=dimension(x) and B=dimension(y) both expressed in [mm]) and the pixel dimensions of the image are likewise known (according to the acquisition definition of px=pixels in x-direction and py=pixels in y-direction), associating a step ppx =A [mm]/px e ppy =B [mm]/py.

The images acquired with this logic are transmitted to VT-Data to be processed and transformed into numerical matrices in which with each step there is associated a level z [mm] and two levels x [mm] and y [mm] obtained from the plane image, having associated the colour W/B (white and black) and the position by numbering the image pixels and utilizing the steps ppx and ppy. In this manner one obtains the set of the spatial points that define the external surface of the surveyed object obj, i.e. the 3D numerical matrix of the object.

Coordination: Hereinbelow we shall set out the logic steps that describe the generation of the 3D numerical matrix and its utilization:

1. acquisition of the images obtained from a object <u>obj</u> taken as model in standard formats;

2. transformation of the images obtained from a object <u>obj</u> taken as model into the equivalent numerical W/B format (1 or 0);

3. transformation of pixel data into real levels along the <u>x</u> and <u>y</u> axes;

4. association of the acquired image sequence with the dimensional parameter of the vertical <u>z</u> axis level;

5. ordering of the data into the 3D numerical matrix = [x, y, z].

The following points 1 – 5 are developed in detail:

1. Acquisition of the image in standard formats.

The images normally acquired by means of a digital system, a photo camera or a video camera for example, are represented in formats of the type:

BMP	1-bit, 4-bit, 8-bit, and 24-bit uncompressed images; 4-bit and 8-bit run-length encoded (RLE) images
JPEG	Any baseline JPEG image; JPEG images with some commonly used extensions
PCX	1-bit, 8-bit, and 24-bit images
TIFF	Any baseline TIFF image, including 1-bit, 8-bit, and 24-bit uncompressed images; 1-bit, 8-bit, and 24-bit images with packbits compression; 1-bit images with CCITT compression

For each format the images are referred to pixel/square inch: image points per square inch. Each image point is associated with a colour that, in its turn, can be scaled in bit formats of the type:

1-bit	Colours white and black W/B
4-bit	Colours in gray scale from 1 to 16
8-bit	Colours from 1 to 16
24-bit	Colours from 1 to 256

2. Transformation of the images into the equivalent numerical W/B format (0/1).

The information needed by the module VT-Data is bound up with the management of the colours W/B. The information system transforms all the acquired images into 1-bit formats. The numerical matrix obtained by means of this transformation contains numerical information of the 0/1 type for every image pixel. The value 0 is associated with the colour black, the value 1 is associated with the colour white, or vice versa.

One thus obtains a matrix B/W = [m, n] where:

m	= number of pixels along x-axis = px
n	= number of pixels along y-axis = py

3. Transformation of pixel data into real levels along the x and y axes.

The resolution of the image depends on the characteristics of device used for data acquisition and on an initial image resolution choice. Given the real dimension of the acquired surface A = dimension (x) and B = dimension (y) in [mm]. Given also the image resolution in pixels px = pixels in the x-direction, and py = pixels in the y-direction .

If the pixel information is to be related to an exact and real scale, it is

necessary to operate as follows:

Symbol	Operation	Description
Ppx	= A [mm]/px	Pixel step along x-axis
Ppy	= B [mm]/py	Pixel step along y-axis

The whole of the pixel information is scaled on the basis of the ppx and ppy ratio and generates the double matrix DM (m, n) constructed as follows:

$$DM = [(i * ppx,\ j * ppy)] \qquad \text{where } i = 0 : n\text{-}1, \quad j = 0 : m\text{-}1$$

so that the colour information contained in the B/W matrix is associated with the matrix DM of the dimensional steps, likewise of dimension [m, n].

Written in extended from, the matrix DM can be expressed as follows:

$$\begin{array}{llllll} DM = [& (0, 0) & (0{+}ppx, 0) & (0{+}i\ ppx, 0) & \dots & (0{+}(n{-}1)\ ppx, 0) \\ & & & & \dots & \\ & (0, 0{+}ppy) & (0{+}ppx, 0{+}ppy) & (0{+}i\ ppx, 0{+}ppy) & \dots & (0{+}(n{-}1)\ ppx, 0{+}ppy) \\ & (0, 0{+}i\ ppy) & (0{+}ppx, 0{+}i\ ppy) & (0{+}i\ ppx, 0{+}i\ ppy) & \dots & (0{+}(n{-}1)\ ppx, 0{+}i\ ppy) \\ & \dots & \dots & \dots & \dots & \dots \\ & (0, 0{+}(m{-}1)\ ppy) & (0{+}ppx, 0{+}(m{-}1)\ ppy) & (0{+}i\ ppx, 0{+}(m{-}1)\ ppy) & \dots & (0{+}(n{-}1)\ ppx, 0{+}(m{-}1)\ pp \end{array}$$

4. Association of the image sequence with the parameter of the vertical z axis level.

The nz images acquired by the system are associated with the vertical level parameter z, which represents the depth (thickness) of the object obj. Each matrix BW is associated with the corresponding acquisition sequence number nz.

The nz matrices BW_{nz} are arranged in order. The depth z of the object obj

and the acquisition number nz determine the vertical scale parameter pnz with:

$pnz = z\ [mm] / nz$

Given thus the nz matrices BW, one defines the summation matrix C as:

$C = \Sigma\ (BW)_{1,nz}$ type (m ,n)

multiplied by dimensional depth parameter, this enables us to define Cr as:

$Cr = C * pnz$ type (m, n),

5. Ordering the data in the 3D numerical matrix = [x, y, z]

The final matrix that represents the external surface of the object obj, defined as the numerical matrix 3D = [x, y, z] is made up of:

3D = [x, y, z] = [DM (i,j) Cr (i,j)]

i = 1 : m

j = 1 : n

DM (i,j) represents the pair of numbers x(i) y(j), the plane coordinates of the point; Cr (i,j) represents a number Cr (i,j) = level z of the point.

Ordering: use of the numerical matrix 3D for the reproduction in a PC of the external surface of a object obj taken as model into a virtual object obj; use of the numerical matrix 3D for the reproduction, by means of the module VT-MF, and the thermoforming in plastic material, by means of the module VT-MT, of the external surface of the virtual object obj obtained from a object obj taken as model to be transmitted to another place or from data obtained from CAD data conserved in a database.

The acquired data can be managed in the following ways:

a) wholly managed by means of dedicated software, specifically developed for acquiring the images and processing them in accordance with the indicated logic;

b) managed by means of a specifically developed hardware (dedicated chip) capable of acquiring, processing and imparting data at high speed, as per the indicated logic, and by a software part of the user interface. This hardware may be integrated into the motherboard of the PC or integrated into an additional board.

(ii) Module VT-MS: having obtained the mechanical survey of the external surface of the object obj taken as model by means of the module VT-MM and fixed the external surface obtained in this way by means of the appropriate fixing system (Figure 5), the plate PL of the needle containment system arranged parallel and frontally on the matrix VT-MM is free to slide along the direction of the length of the needles; the plate PL, which has a thickness Sp, is rigidly constrained to slide in a direction parallel to the x-y plane in the direction of the module VT-MS (Figures 10 and 11). An electronically controlled kinematic mechanism to which the plate PL is bound enable the plate to perform a movement along the z-axis and this movement may be either continuous or in predetermined steps. The plate PL contains all the needles of the matrix of the module VT-MM and, more specifically, the needles that are arranged as the external surface of the object obj taken as model. Commencing from the point Z=0, the parallel and frontal plate PL in contact with the upper flat space of the module VT-MM placed in parallel with the module VT-MS constitutes the first image that the photo-optical image survey system (photo camera or video camera) of the module VT-MS acquires. This first image has all the needles of the matrix in view; the subsequent step of the plate PL, i.e. a position Z=0 + nst ∘ step (where nst=step number and step= distance between two steps), implies the acquisition of a new image with all the needles less the ones that are no longer present on the plane of plate PL in the position nst=1. Proceeding sequentially in this manner, one obtains a set of image mappings of the plate PL planes corresponding to the various steps, i.e. of the distance of PL from the

plane Z=0.

Two or one series of image photograms of identical dimension and file format are then acquired by means of photo camera or video camera and are translated into white and black images (W/B=0/1), 1-bit format.

The images taken by the chosen item of equipment (photo camera or video camera), ordered in such a manner that each ray arriving from the objective of the employed camera will be aligned with axes that are parallel to each other. An adjustment system makes it possible to select and accurately align the acquired image frame (cropping area), managing and displaying only the cropped area, so that possible distortions deriving from the employed optical system (photo camera or video camera) are parameterized by means of mathematical rectification operations integrated in the calculation module VT-Data.

When the images are acquired by means of a photo camera, the number of the images in sequence from 1 to <u>n</u> is associated with the step position of the plane PL. In other words, image 1 corresponds to displacement step 1 of the plane PL, image 2 to step 2, and so on.

When the images are acquired by means of a video camera capable of shooting at the rate of <u>nf</u> [images/s] images per second and the displacement of the plane PL is continuous at a speed of <u>Vz</u> [mm/s], the shooting parameters are associated in the following manner:

Using <u>t</u> to designate the generic shooting instant measured from the beginning of the movement sequence: video camera shooting / movement of the plane PL, we define:

N image = image number = t * nf

S image = displacement associated with image N image = t * Vz

When the shooting parameters nf and Vz are formulated in this manner, it becomes to define the definition of the 3D numerical numerical matrix of the object obj by dividing the total shooting time T into a number n such that t = T/n = step of time interval between two consecutive images: in this manner, increasing n, one also increases the definition of the 3D numerical matrix.

Example:

1. Given a photo camera capable of acquiring images at the rate of 30 images per second = nf [images/s];
2. Given the speed of movement of the plane PL as equal to 0.5 mm/s = Vz [mm/s];
3. Having chosen a scanning definition equal to n = 25;
4. Given a total acquisition time of 5 seconds = T;
5. One acquires 5 * 30 = 150 images;
6. The definition N of the dimensional parameter along the z-axis is given:

t = T/n = 5 /30 = 1/6

N = t * nf = 1/6 * 0.5 = 0.083 mm

The shooting photograms to be used are scaled at: 150/25 = 6, i.e. use will be made of the photograms 1, 1+6, 1+12, 1+18, (...), that is to say, starting from 1 and proceeding in steps of 6 up to 150; to every 1, 1+6, 1+12, 1+18 (...) there corresponds a displacement of 0, 0+1*0.083, 0+2*0.083, 0+3*0,083 (...).

The electronic circuit (integrated system of the module VT-Data) makes it possible to program the sliding of the plate PL to coincide with the gradual linear unfolding of the film footage in frames/image (when one has opted for a video camera) or the sequence of successively taken images (when one has opted for a photo camera).

The survey of the external surface of the object **obj** is obtained also by

interfacing the needle matrix of the module VT-MM with a sensitive acquisition plane such as a sensor table. The sensor table surface moves along z direction and reports the needle coordinate. Module VT-data uses this information as an image information and refers to the above example where the sensor table corresponds to the PL plane.

(iii) Module VT-MM: The module comprises a needle matrix, wherein a plurality of needles, uniformly distributed and all of equal size, can slide freely. The needles of equal length, arranged in parallel with each other and capable of moving independently and positioned in the matrix that contains them in a configurations that maintains uniformly distributed in their seatings, are ordered perpendicularly to a horizontal plane in the application module with the single-matrix e or ordered parallel to a horizontal plane in the application module with two parallel matrices.

More generically, we shall say that the module VT-MM comprises, as described, a needle matrix and plates holed at specific intervals, where the density ds of the holes may vary from 10 to 20 holes per sq.cm and even more.

In each hole there slides a metallic indicator of the rod type, that is to say, of a consistency and thickness such as to be capable of transferring precise axial actions without producing flexural actions during the thermoforming exercise of the specific thermoplastic lamina (sheet) having a weight per unit area and a mix calculated to assure the correct functioning of the thermoforming module VT-MT that interfaces with the module VT-MM.

Each needle (generic name of the element), which has an indicative length La comprised between 100 and 200 mm and even more, has a diameter da = 1–2 mm and even less. The holing density, the respective diameter of the needles and the length La are interrelated on the basis of the desired surface reading definition. A needle matrix is characterized by the general parameters: La, da, ds and by its dimension A*B.

The matrix sets with identical parameters A*B, but with different values of <u>La</u>, <u>Da</u>, <u>da</u>, are interchangeable within the casing of the module VT-MM in such a way as to make it possible to change the reading/reproduction definition of the object <u>obj</u> that is to be thermoformed, acquired virtually or reproduced.

The needles of the matrix of the module VT-MM slide freely within the holes of their containing and locking plates; when all the needles of the module VT-MM have reached the external surface of the pre-existing object <u>obj</u> taken as model, it is possible to block them in their position by acting on the lateral locking pins of the plates. The needle locking plates are holed plates with a holing density <u>ds</u>, a hole diameter that exceeds the diameter of the needle inserted in the hole by 0.1 mm (indicative measurement to be understood as search for the minimum clearance compatible with the free movement of the needle) and have slotted holes at their lateral edges to permit passage of the locking pins. The locking plates are 4 in number or some multiple of 4, including 2 that lock in the direction +/- <u>x</u> (direction of side A) an 2 that lock in the direction +/- <u>y</u> (direction of side B). The fixing pins moving in their respective seatings to interact with the needle locking plates, forcing displacements in the plane perpendicular to the degree of freedom of the needles (this displacement can be realized with another ordered method). Though depending on the chosen resolution (ds), the needles blocked in this manner accurately reproduce the external surface of the pre-existing object <u>obj</u> taken as model at the opposite vertex of the needles in contact with the object <u>obj</u>.

Then heads of the needles that reproduce the external surface of the pre-existing object <u>obj</u> taken as model surveyed (ascertained) by the module VT-MM will be covered by a thin protective sheath made of flexible and elastic material capable of resisting the forming temperature (teflon, for example) when the module VT-MM is

interfaced with the module VT-MT; but these needle heads will be free when the module VT-MM is interfaced with the modules VT-MS and VT-MF. This thin sheath, arranged in a fixed position as a lining or cladding on top of the needle heads of the module VT-MM onto which there is laid the specific plastic material that is to be thermoformed (ordered once again superposed and parallel to the needle tips of the module VT-MM interacting with the module VT-MT), has the task of constituting a separation gasket, support and compensation during the exercise of the thermoforming of the panel of thermoplastic material placed on top of it.

The module VT-MM is the component that renders possible the mechanical survey of the external surface of a pre-existing object <u>obj</u> taken as model; the external surface surveyed in this manner is formed the panel of thermoworkable material in the thermoforming module VT-MT that interfaces with it; the transformation (acquisition of VT-Data) of the external surface of the pre-existing object <u>obj</u> taken as model into informatics data (coordinated by VT-Data) is rendered possible by the module VT-MS interfaced with it; the transmission and reproduction (ordered by VT-Data) in thermoformable plastic material of the external surface of a virtual object <u>obj</u> obtained CAD data conserved in a database and/or the reproduction of the external surface of a pre-existing object <u>obj</u> taken as model previously digitalized is carried out by the modules VT-MF and VT-MT interfaced with it.

(iv) Module VT-MP: The high-precision matrix module VT-MP makes it possible to survey outlines with particularly great accuracy.

Its operating principle consists of the utilization of a needle matrix in which the needle axes are concentric with respect to a vertex, hereinafter referred to as the matrix focus.

The needle matrix constructed in this manner, which is shown in Figure 16,

has the needles arranged on a spherical segment (dome), and the axis of each needle converges on the matrix focus; on the reading side, where the object obj to be surveyed is situated, the needles are very close to each other, in the limit with zero distance between adjacent needles and therefore maximum reading definition.

On the opposite side of the matrix (Figure 17) the needles are arranged along the directrix of the focus, forming an enlarged ideal surface, with each point proportioned on the basis of its position with respect to the spherical coordinate system; the spherical enlargement factor will hereinafter be indicated by $I(R, \alpha, \theta)$.

The matrix constructed in this manner makes it possible for even very small surfaces (outlines) to be surveyed with great precision.

In mathematical terms, the system transforms the reading of the outline into a spherical coordinate system of the type $R(\alpha, \theta)$, where:

$R =$ radial distance between the surface and the focus

$\alpha =$ angle in the vertical plane of the directrix R

$\theta =$ angle in the horizontal plane of the directrix R

The reading of the outline is also a function of the length La of the needles, i.e.:

$$Z(\alpha, \theta) = R(\alpha, \theta) + La \cos(\alpha)$$

The outline is read (Figure 17) by bringing the object obj into contact with the matrix VT-MP and then, after having blocked the needles, always with the help of the system of lateral pins, the thermoforming module VT-MT is brought alongside and the surface proportioned in accordance with $Z(\alpha, \theta)$ is reproduced in thermoformable plastic material.

The surface $Z(\alpha, \theta)$ produced in this manner is brought into direct contact with the module VT-MM and the mathematical information relating to the surface $Z(\alpha, \theta)$ is read by means of the module VT-MS.

A mathematical re-proportioning system, which takes account of the enlargement factor associated with the position $I(R, \alpha, \theta)$, transforms the received information $Z(\alpha, \theta)$ into the three-dimensional mathematical representation system 3D = [x,y,z], information that represents the precise mathematical expression of the surveyed surface.

R	Radial distance between the surface and the focus
α	Angle in the vertical plane of the directrix R
θ	Angle in the horizontal plane of the directrix R
$Z(\alpha,\theta)$	Surface of external outline VT-MP
$I(R,\alpha,\theta)$	Spherical enlargement factor

(v) Module VT-MT: This module constitutes a chamber with five walls and lacking the bottom wall (in use arranged in accordance with the single-matrix module perpendicular to the plane) or the side wall (in use arranged in accordance with the parallel double matrix) that can be lowered or translated sideways so that its lower or lateral perimeter edge comes to lie against the frame of the needle matrix module VT-MM, defining the thermoforming module constituted by the upper wall, part of the side walls and the panel of a specific thermoformable plastic material that embraces with its perimeter the entire plurality of needles in the single-matrix module (see Figure 1) or defining the thermoforming module comprised between the upper wall, the lower wall, part of the side walls and the panel of thermoformable plastic material that embraces with its perimeter the whole of the plurality of needles in the parallel double matrix translating along the supporting plane (see Figure 2).

The edges of the panel of the plastic material to be thermoformed (the size

of which is equivalent to or greater than the area that constitutes the perimetral surface of the needle matrix contained in the module VT-MM) are accommodated on the external frame of the structure constituting the matrix, squeezed by the compression applied by the perimetral ends of the walls of the fie-walled chamber of the module VT-MT and the module VT-MM itself, so that the modules will prove to be gas-tight injected by means of a duct at a pressure suitable for keeping the thermoformable panel pressed against the surface of the heads of the needles of the module VT-MM for the time that is needed for the heat generated in the module VT-MT by an electrical resistance or some other method to fix the thermoplastic panel in the form assumed by the needles.

The plane on which there rests the model intended to be pressed against the needles ends of the module VT-MM (lower end of the needles when using the single-matrix application perpendicular to the plane, and end of the needles in contact with model and arranged in parallel with the plane when using the module with two parallel matrices) constitutes the modelling space.

The electronic system of the integrated module VT-Data imparts (imposes) the actions for adjusting the operating temperature of the employed heating method, moving the module VT-MT by means of compressed air and regulating the injection of the compression agent and its pressure (gas injected into the chamber).

(vi) Module VT-MF: Being directly interfaced with the module VT-MM, this module permits the reproduction on the selfsame module VT-MM of the external surface of a pre-existing object <u>obj</u> taken as model and/or the reproduction of the external surface of a virtual object <u>obj</u> obtained from CAD data conserved in a database and, whenever required, its subsequent thermoforming by means of the module VT-MT. The module VT-MF consists of a shell that at its open ends provides

the coupling surfaces for constituting a modular composition with the module VT-MM. Within the shell there is present a space that is open on the side that serves for coupling the modules VT-MT and VT-MM; the space contains a system with three controlled axes (ordered by VT-Data) arranged in parallel with the module VT-MM. Referring to Figure 12, we shall now describe the basic structure of the system with the three axes Ax, Ay, Az as indicated in the figure. The first axis Ax works on the cross-piece in the x-direction supported on the ends of the sides; the second axis Ay works along the y-direction; the third axis Az works vertically in the z-direction, moving a rod that has to be positioned at the desired level.

The 3D numerical matrix generated by the integrated calculation module VT-Data, which describes the previously digitalized external surface of the object obj taken as model or the external surface of any virtual object obj obtained from CAD data conserved in database, is used to set the positions of the three controlled axes. With each generic surface point P_i having the coordinates (x,y,z) the system associates the corresponding displacement of the axes required in order to position the vertex of the rod exactly at the point P_i; the system use as reference the point having the coordinates (0, 0, 0).

Positioning itself at the required point P_i, the rod forces the position of the needle with the displacement actuator to be found at the given coordinates (x,y) of the needle matrix of the module VT-MM and thus generates the coordinate z associated therewith.

This operation is performed for all the points of the previously digitalized external surface of an object obj or the external surface of any virtual object obj obtained from CAD data conserved in a database that it is proposed to reproduce.

The transfer of the data of the 3D numerical matrix from the integrated

calculation module VT-Data to the control system of the axes (it is possible to have a positioning means with several z-axes plus an x-axis and a y-axis at the same time) is effected by means of a specifically dedicated system that controls the positions and optimizes the working times.

Always with the help of the integrated calculation module VT-Data, it is also possible to reformulate and rescale the numerical information of the 3D numerical matrix, for example, to scale a format $(A, B)_1$ into a format $(A, B)_2$: so that, if $(A, B)_1$ is of a dimension equivalent to an A4 paper format (297*210), it is possible to reproduce in a format $(A, B)_2$ of dimension equivalent to an A3 paper (420*297) by scaling the reproduction in the same proportion (420/297=1.41 = 297/210=1.41) or by maintaining the reproduction scale <= 1.41.

On the surface of the needle matrix of the module VT-MM opposite the one on which we have forced the needle positions by means of the controlled axes, that is to say, on the side to which the thermoforming module VT-MT can be coupled, we obtain at the end of the positioning process the shape of the external surface of the object obj it is proposed to thermoform from a thermoplastic panel.

The electronic photo-optical system with the devices and functionalities as described hereinabove has the characteristic that it can be configured in various ways.

The possible configurations about to be described make it possible for the system to be personalized in accordance with particular needs and the selected parameters.

The table reproduced below summarizes the possible variants, module by module:

Module	Parameter 1	Parameter 2	Parameter 3	Description
VT-MM / VT-MP	Side A (x-axis)	Side B (y-axis)	Needle density Needle diameter Needle length La	Device dimensions and needle resolution
VT-MT	Side A (x-axis)	Side B (y-axis)	Plastic panel for thermoforming	Dimensions, weight per unit area specific formulation of material to be thermoformed
VT-MF	Side A (x-axis)	Side B (y-axis)	Number of controlled axes	Device dimension
VT-MS	Side A (x-axis)	Side B (y-axis)	Type of digital acquisition, resolution and definition	Photo camera or video camera. Resolution 320*240 / 640*480 / 1600*1200 pixel etc.). Definition: number of images per [mm]
VT-Data	In Data	Out Data	Format Data:	Input: bmp, jpeg, pcx, tiff, etc., from VT-MS; edicated output direct to VT-MF, VT-MT / On PC as image / On PC as CAD file

The particular feature of this electronic photo-optical system made up of modules is that it can be personalized by changing the parameters 1 and/or2 and/or 3 of the above table of variants in accordance with particular needs.

The number of needles per sq.cm can be varied according to requirements and the need of obtaining a greater or a lesser resolution of details. Applying this principle, the system can dispose of infinite numerical needle use combinations. The support of the needles, likewise, need not be of pre-established size and shape and once again benefits from the prerogative that it can be made to measure for each case and specific request (matrix square, rectangular, circular, etc.); the constitution of the core of the needles (rods) always transfers nothing but precise axial actions without causing any flexural actions during the thermoforming of the specific plastic panel that is being used with them and the correct mixture formulation of this panel, which has to be carefully considered, assures the proper functioning of the modules VT-MT and VT-MM.

Quite apart from a standardized serial production of the device, it has the property of that it can be realized in infinite numerical combinations of needles and sizes of the needles and the matrix, which latter, in its turn, can have different plan shapes and sizes, while the system with three controlled axis of the module VT-MF may have n axis.

The needles of the matrix module VT-MM may also be made of a thermoplastic material such that the needles may become united following the action of an appropriate heating agent capable of dilating and increasing the diameter of their section, uniting them with each other in permanent form along their entire extension.

The needle matrix of the module VT-MM may not have its needles constrained by the scanning plate PL and the locking grids, so that the needles will be distributed in

parallel and in direct contact with each other and blocked relative to each other by the containing frame constituting the perimeter of the matrix of the module VT-MM and having sufficient possibility of slipping in order to slide and become displaced relative to each other according to an appropriate and pre-defined dilation of the perimeter of said containing frame, said containing frame being capable of immobilizing them (again) following an appropriate shrinking of the perimeter.

Claims

1. A system for thermoforming, digitalizing and reproducing in three dimensions the external surface of an object (obj/22), virtually and/or in thermoformable plastic material, using a needle matrix (VT-MM/21) that surveys the external surface of the object, **characterized** in that it comprises:

an integrated module for the mathematical calculation and management of the informatics data (VT-Data/31, 32, 33, 34);

a high-precision matrix module (VT-MP/35);

- a scanner module (VT-MS/19);
- a module for reproduction by means of fax (VT-MF/20);
- a module for the thermoforming (VT-MT/18).

together capable of performing the following actions:

(1) the mechanical survey, by means of the needle matrix system (VT-MM or VT-MP), of the external surface of the object (22), obtaining its mapping in terms of levels with respect to a reference plane by means of the scanner module (VT-MS/19);

(2) the survey of the external surface of the pre-existing object taken as model by means of said mechanical survey with a first electronic photo-optical device that digitalizes the data thus acquired;

(3) the processing and reproduction of the mathematics that describe the geometry of the external surface of the pre-existing model object obtained by means of the mechanical survey and the said digitalization, as logic indicated from the integrated calculation module (VT-Data/31, 32, 33, 34);

(4) the transfer into the database of a processor the mathematical data acquired for the purpose of reproducing in a PC (31) the external surface of the object

obtained by means of said mechanical survey;

(5) the transfer, by means of a local and/or a remote network, of the acquired mathematical data corresponding to the external surface of the acquired object for the purpose of reproducing in the needle matrix module (VT-MM/21), by means of the module for fax reproduction (VT-MF/20) of a second and remote electronic photo-optical device, the copy of the same external surface and/or the external surface of a CAD processed as indicated logic of the integrated module for the mathematical calculation and the management of the informatics data (VT-Data);

(6) the hot moulding from a panel of thermoformable plastic material of suitable formulation the external surface of a pre-existing object taken as model and/or obtained from CAD data, as from the previous actions.

2. A system in accordance with Claim 1 characterized in that the integrated mathematical calculation and management of the informatics data (VT-Data) generates, starting from information obtained from images, a 3D numerical matrix representing the coordinates $\underline{x}$, $\underline{y}$, $\underline{z}$ of the external surface of the object, said matrix being defined by:

$$3D = [x, y, z] = [DM(i,j)\ \ Cr(i,j)]$$

where $i = 1 : m \quad j = 1 : n$

and:

- DM(i,j) represents the pair of numbers x(i) y(j), planar coordinates of the generic point P_i of the surface;
- Cr(i,j) represents a number equivalent to the level $\underline{z}$ of the generic point P_i of the surface;
- $\underline{m}$ is the number of pixels along the x-axis of the projection of the surface into the plane $\underline{xy}$;

- $\underline{n}$ is the number of pixels along the y-axis of the projection of the surface into the plane $\underline{xy}$;

so that, given a number $\underline{nz}$ of acquired images, of dimensions (m, n) pixels, transformed into numerical information of the 1 or 0 type, corresponding to the colour black and white, i.e. transformed into a number $\underline{nz}$ of matrices of dimension (m, n) containing information of the 1 or 0 type referred to as BW_{nz}, and given the depth $\underline{z}$ of the object and the number of acquisitions $\underline{nz}$, there is defined the vertical scale factor

$\underline{pnz} = \underline{z}$ [mm] / $\underline{nz}$

and, given the $\underline{nz}$ matrices BW, the summation matrix is defined as:

$C = \sum (BW)_{1,\,nz}$ type (m, n)

which, multiplied by the dimensional depth parameter $\underline{pnz}$, defines:

$Cr(i,j) = C * pnz$ type (m, n) .

3. A system in accordance with Claims 1, 2 characterized in that the integrated module for the mathematical calculation and management of the informatics data (VT-Data) takes the following steps :

- formulating the parameters for the acquisition of the information needed by the integrated module for the calculation and management of the informatics data (VT-Data) for ordering the 3D numerical matrix, or formulating the resolution of the optical image survey system and the dimensional level parameters on the $\underline{z}$-axis associated with the movement, be it continuous or in steps, of a scanning plane (PL);

- acquiring the data relating to the external surface of a pre-existing object taken as model;

- mathematically processing the acquired data and translating them into Cartesian coordinates, generating a data file in the 3D numerical matrix;

- managing the data by means of a hardware capable of acquiring and

processing the data at high speed and a user interface software;

- utilizing the 3D numerical matrix for interfacing, by means of translation into CAD format, with the three-dimensional formats of the CAD systems;

- importing data relating to surfaces of objects from CAD systems, translating them into the Cartesian coordinate format of the device;

- processing the data file, making the dimensions of the object conform directly to an arbitrary scale and/or modifying them by means of the CAD import-export system;

- utilizing the 3D numerical matrix obtained from an acquisition or from a CAD import to transmit the data to the reproduction system either locally or via a network.

4. A system in accordance with Claims 1, 2, 3 characterized in that the scanner module (VT-MS/19) surveys images or photogram-images of the needle heads in the blocked configuration of the interfaced needle matrix module (VT-MM), reproducing the external surface of a pre-existing object and the positioning of the reference plate (PL) for the scanning, the plate PL being moved by means of an electronically controlled kinematic mechanism along the extension of the needles; where said movement can be either continuous or in steps, and in case of continuous movement is associated with a video camera take such as to obtain phtotogram/displacement correspondence in a unit of time, while in the case of stepped movement the association is such that to every position of the plate PL there corresponds an image taken by a photo camera.

5. A system in accordance with Claims 1, 2, 3, characterized in that the module for fax reproduction (VT-MF/20) reproduces the external surface of a virtual object ordered by the 3D numerical matrix of the integrated module for the mathematical

calculation and management of the informatics data (VT-Data) by means of a system of Cartesian axes (x, y, z) whose reference point (P) is the vertex of the mechanical actuator that performs its movement along the z-axis corresponding to the extension of the needles (4) of the needle matrix (VT-MM/21), the point of reference (P) forcing the position of the needles one by one, reproducing the entire external surface of the virtual object on the interfaced needle matrix.

6. A system in accordance with Claims 1, to 5 characterized in that comprises a sensitive acquisition plane interfaced with the needle matrix of the module (VT-MM/21) and generating in the PC the virtual outline of the object previously surveyed mechanically by means of said matrix in accordance with an orthogonal Cartesian coordinate logic.

7. A system in accordance with claims 1 to 6 characterized in that the needles of the matrix module (VT-MM/21) are made of a thermoplastic material such that the needles become united following the action of an appropriate heating agent capable of dilating and increasing the diameter of their section, uniting them with each other in permanent form along their entire extension.

8. A system in accordance with claims 1 to 7 characterized in that the scanning plate (PL) and the locking grids are so arranged as not constrain the needles of the module VT-MM so that the needles will be distributed in parallel and in direct contact with each other and blocked relative to each other by the containing frame constituting the perimeter of the matrix of the matrix module (VT-MM) and having sufficient possibility of slipping in order to slide and become displaced relative to each other according to an appropriate and pre-defined dilation of the perimeter of said containing frame, said containing frame being capable of again immobilizing them following an appropriate shrinking of the perimeter.

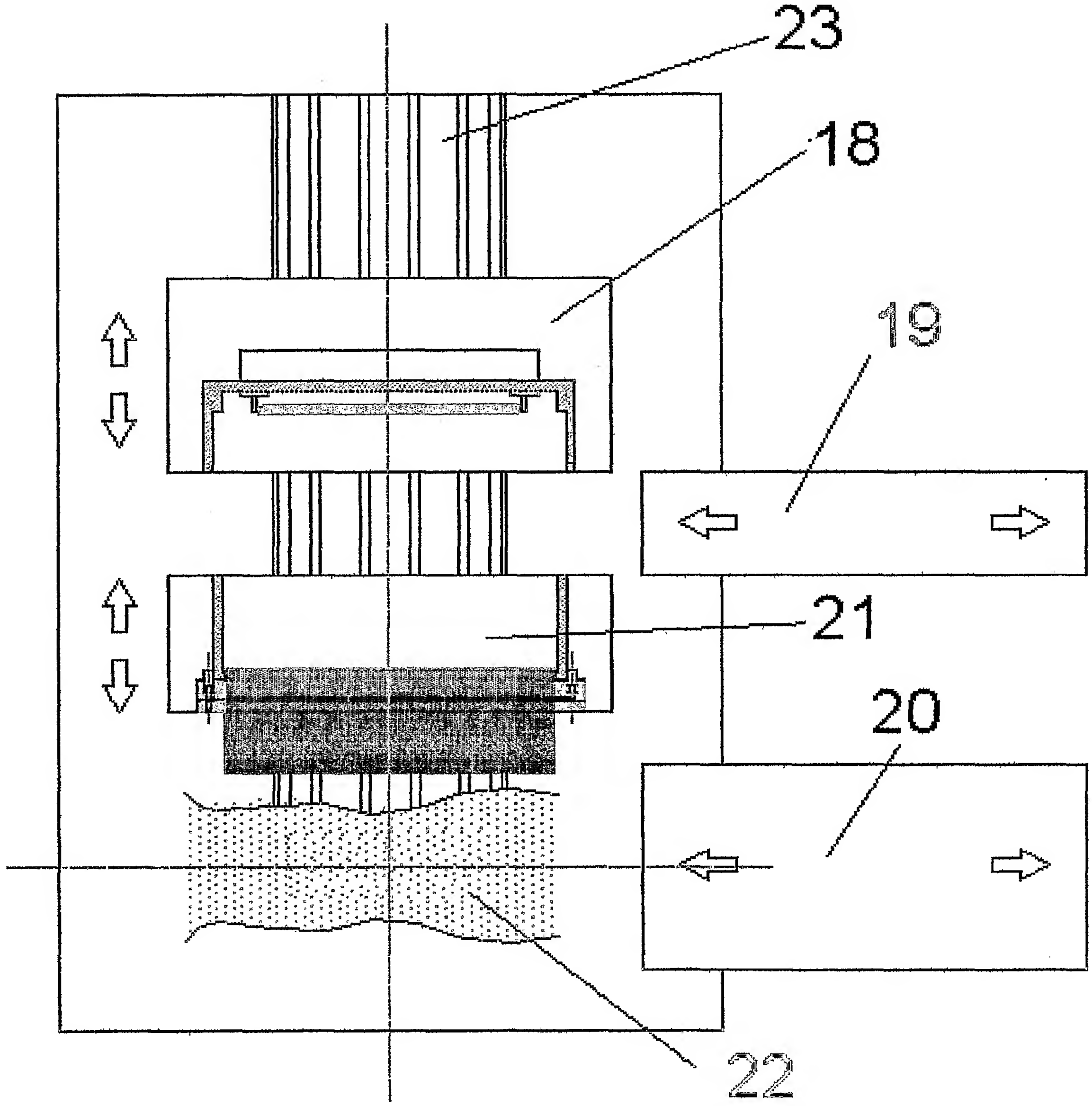

Fig. 1

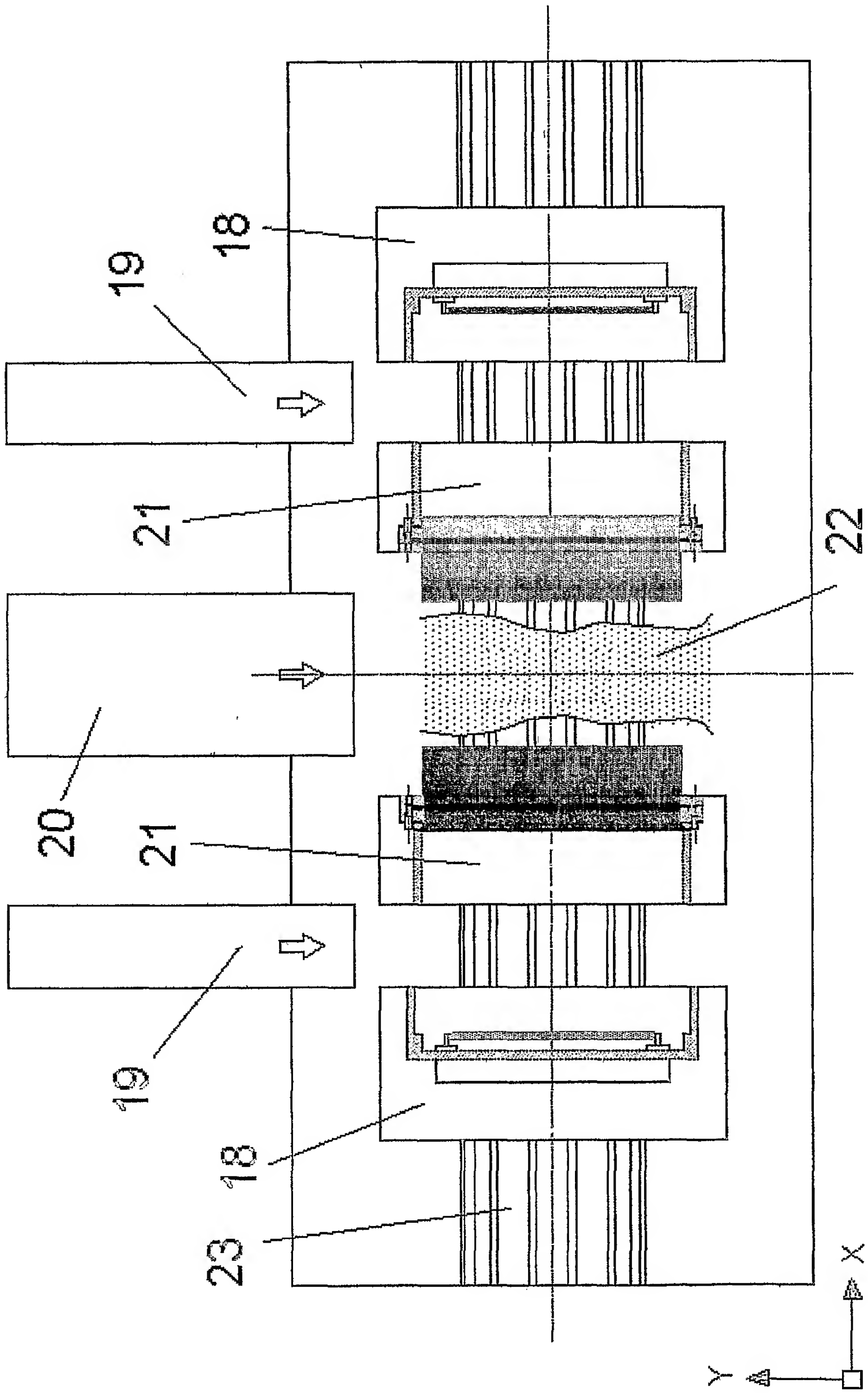

Fig. 2

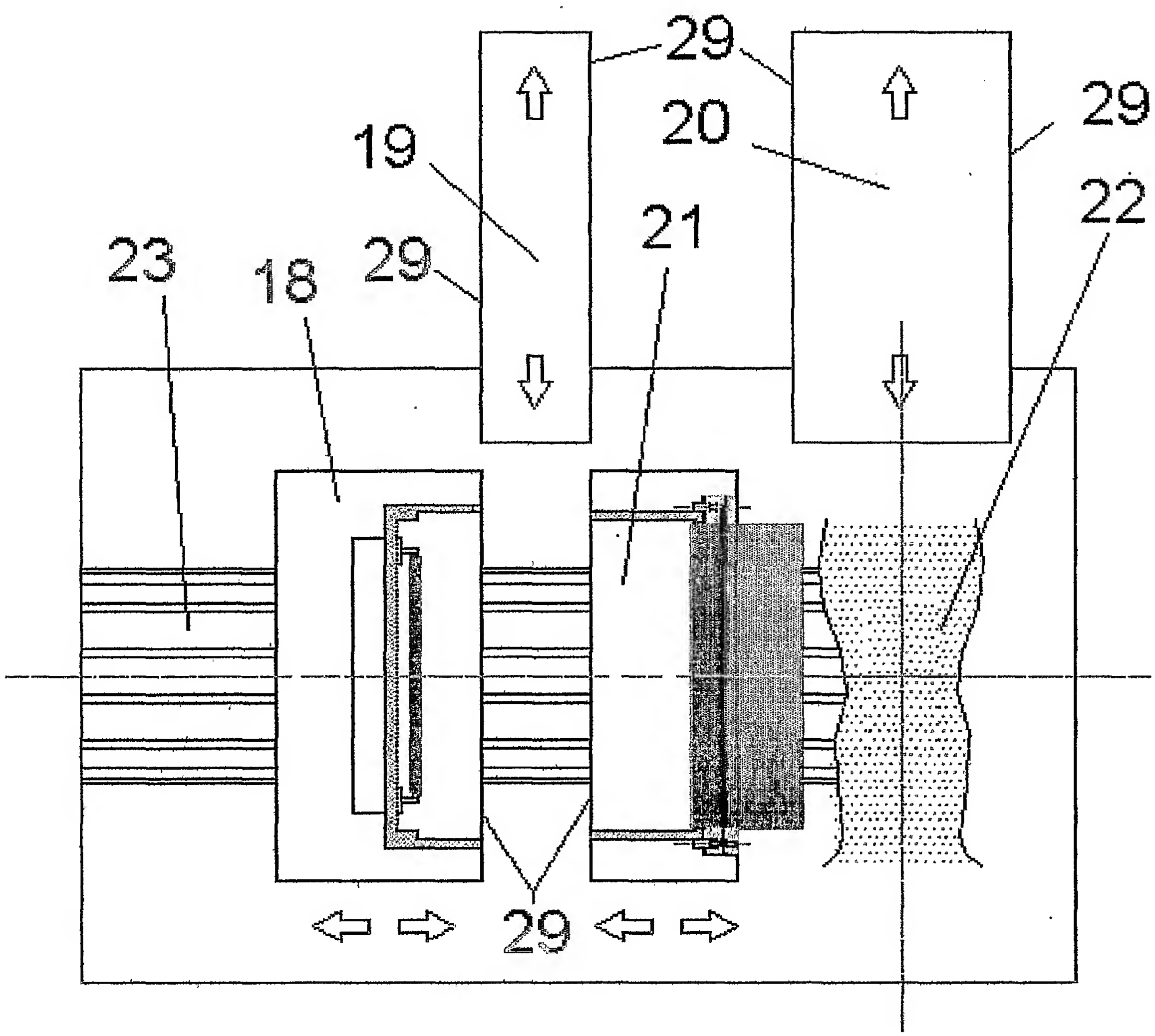

Fig. 3

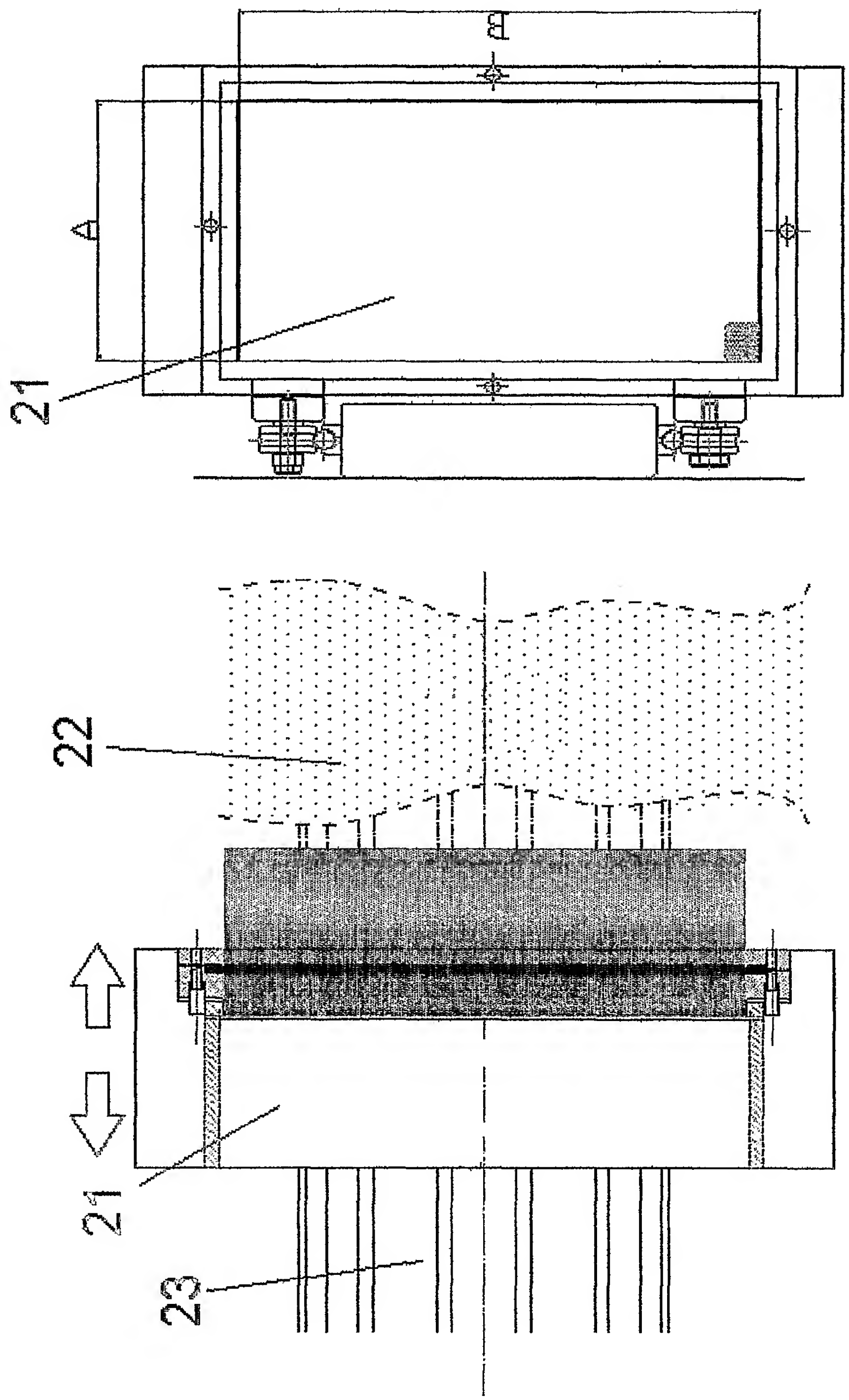

Fig. 4

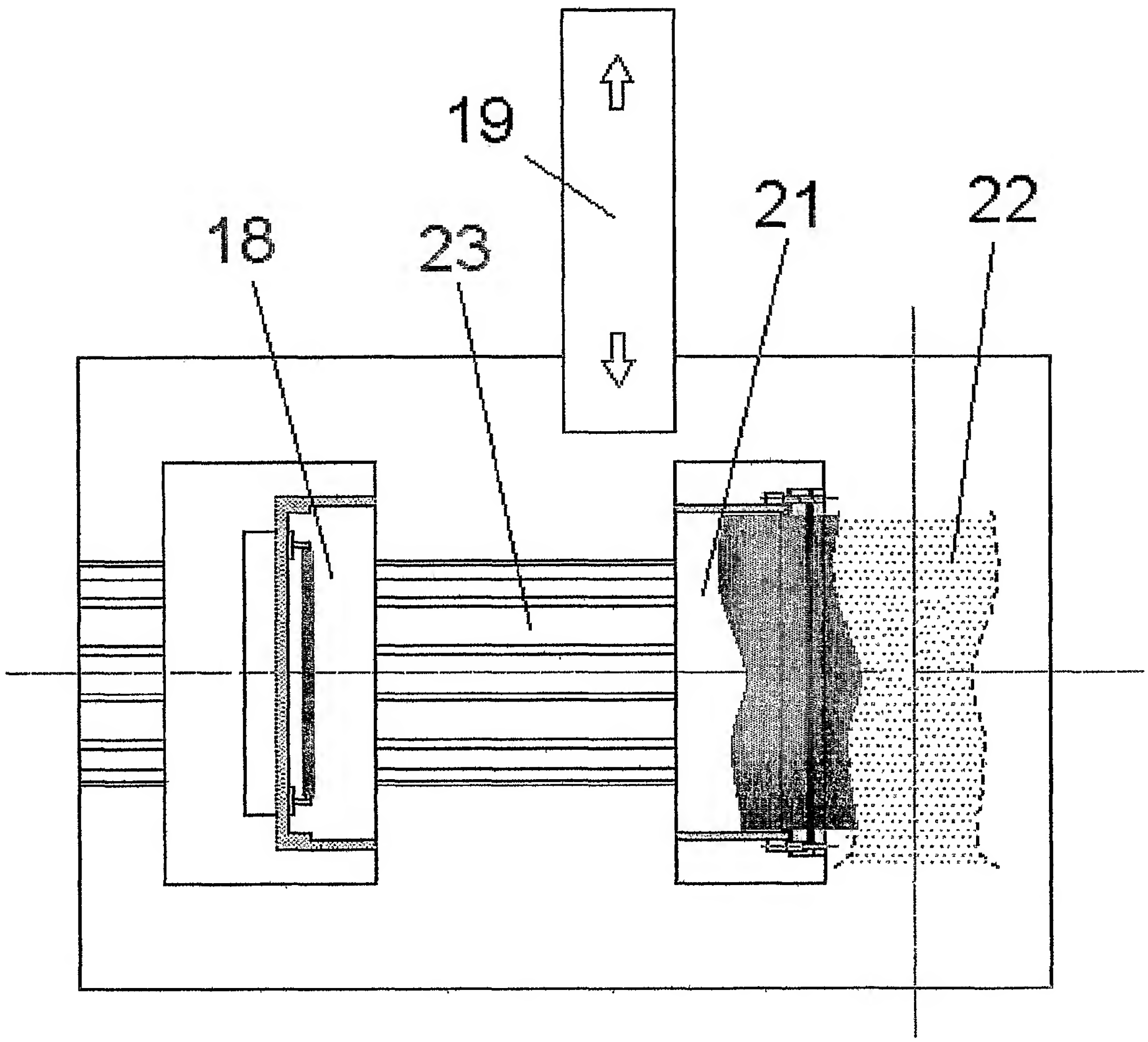

Fig. 5

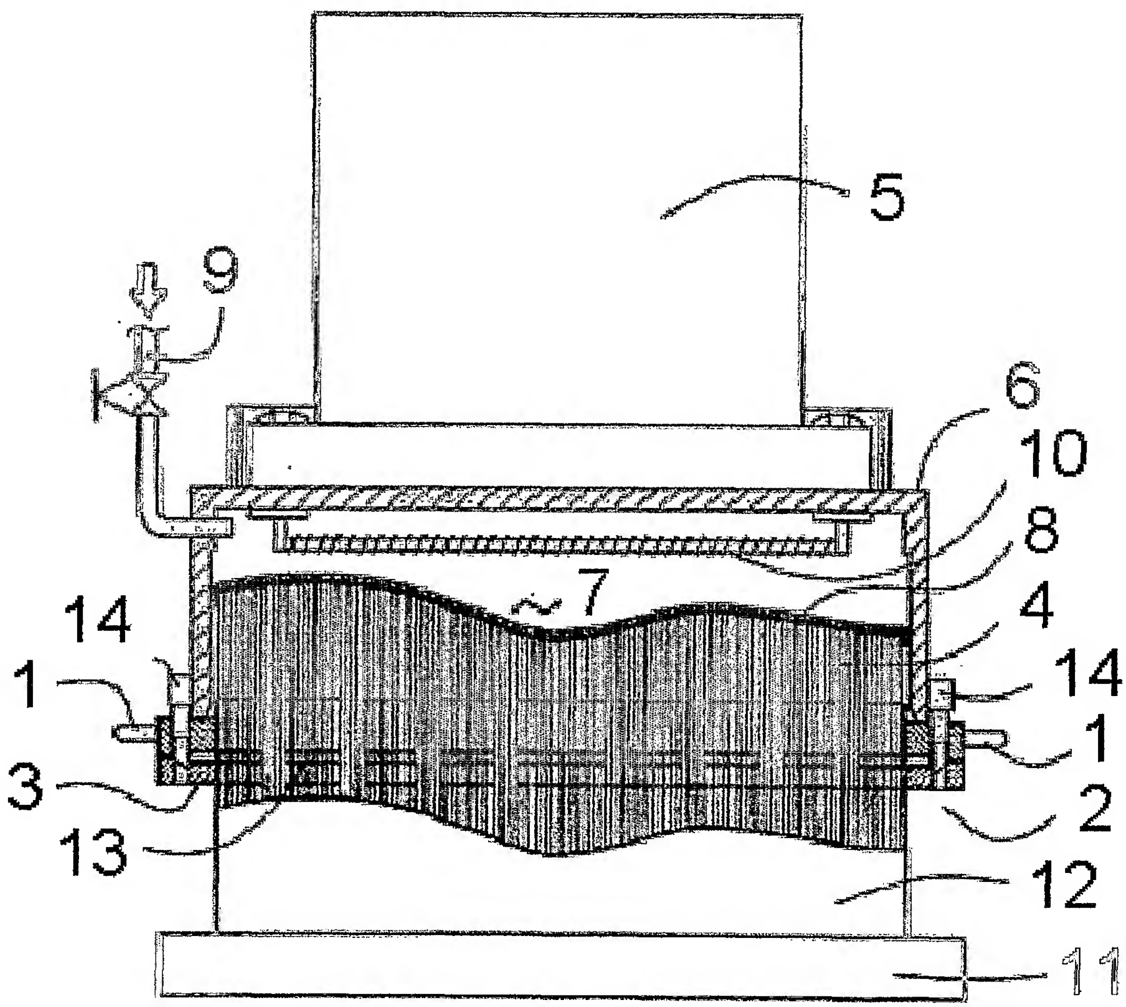

Fig. 6

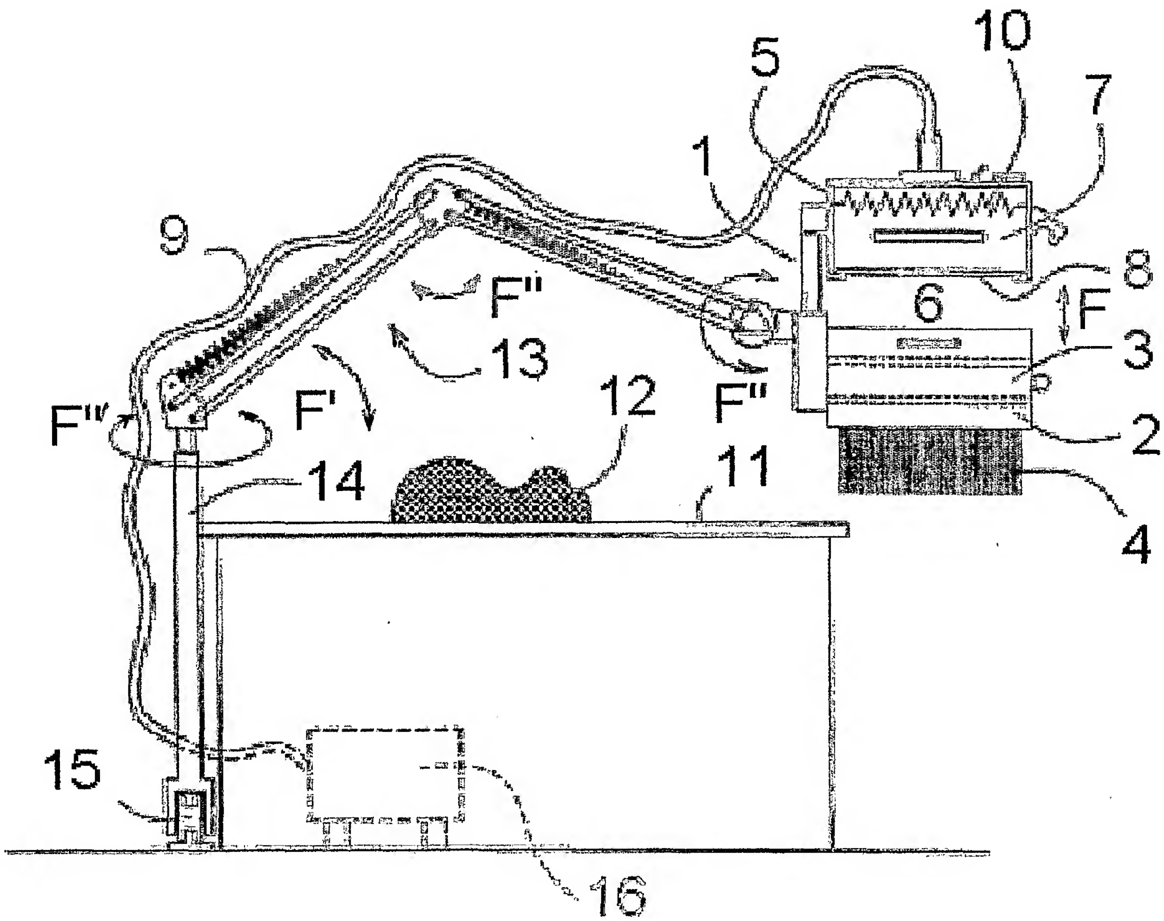

Fig. 7

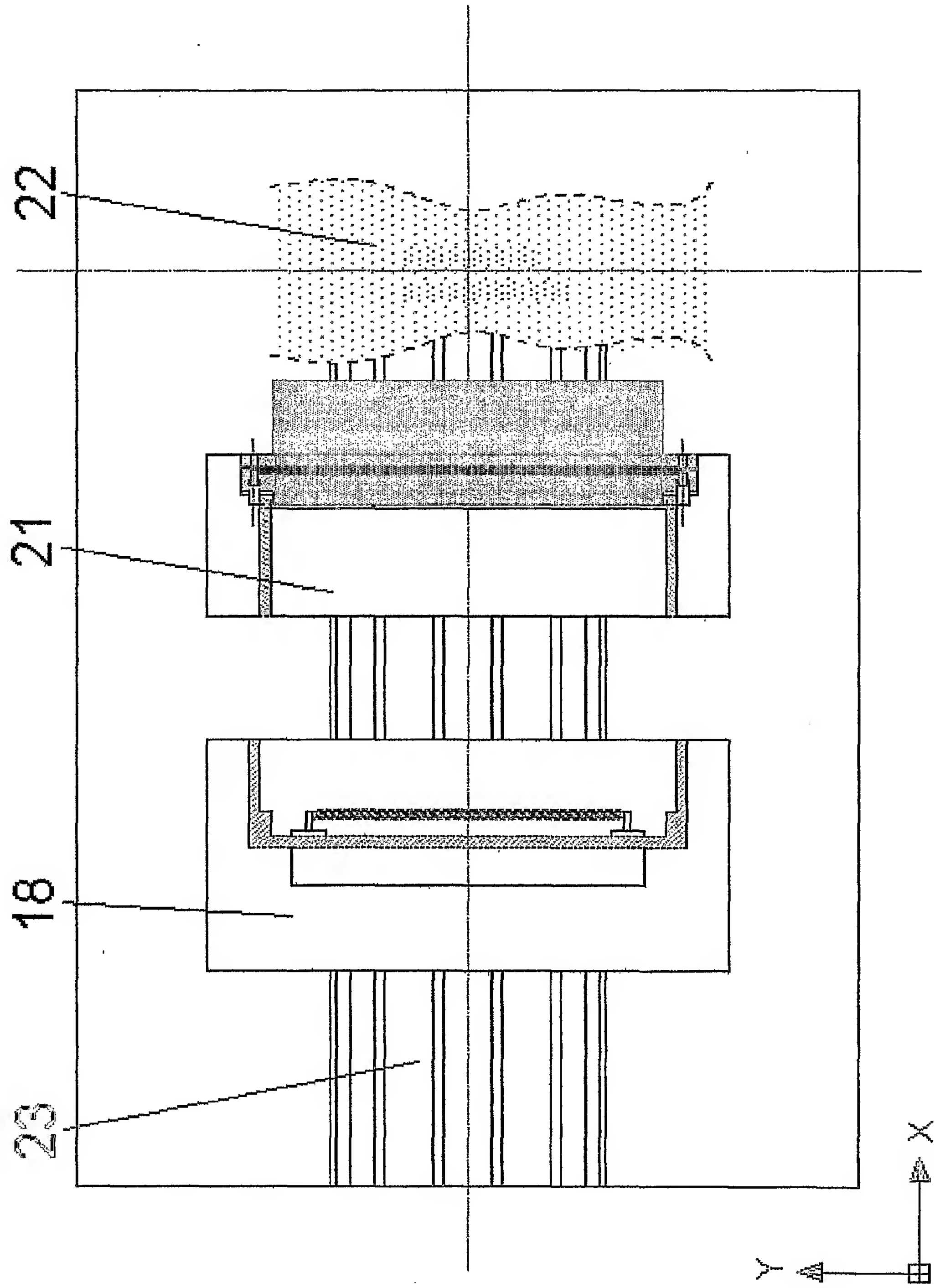

Fig. 8

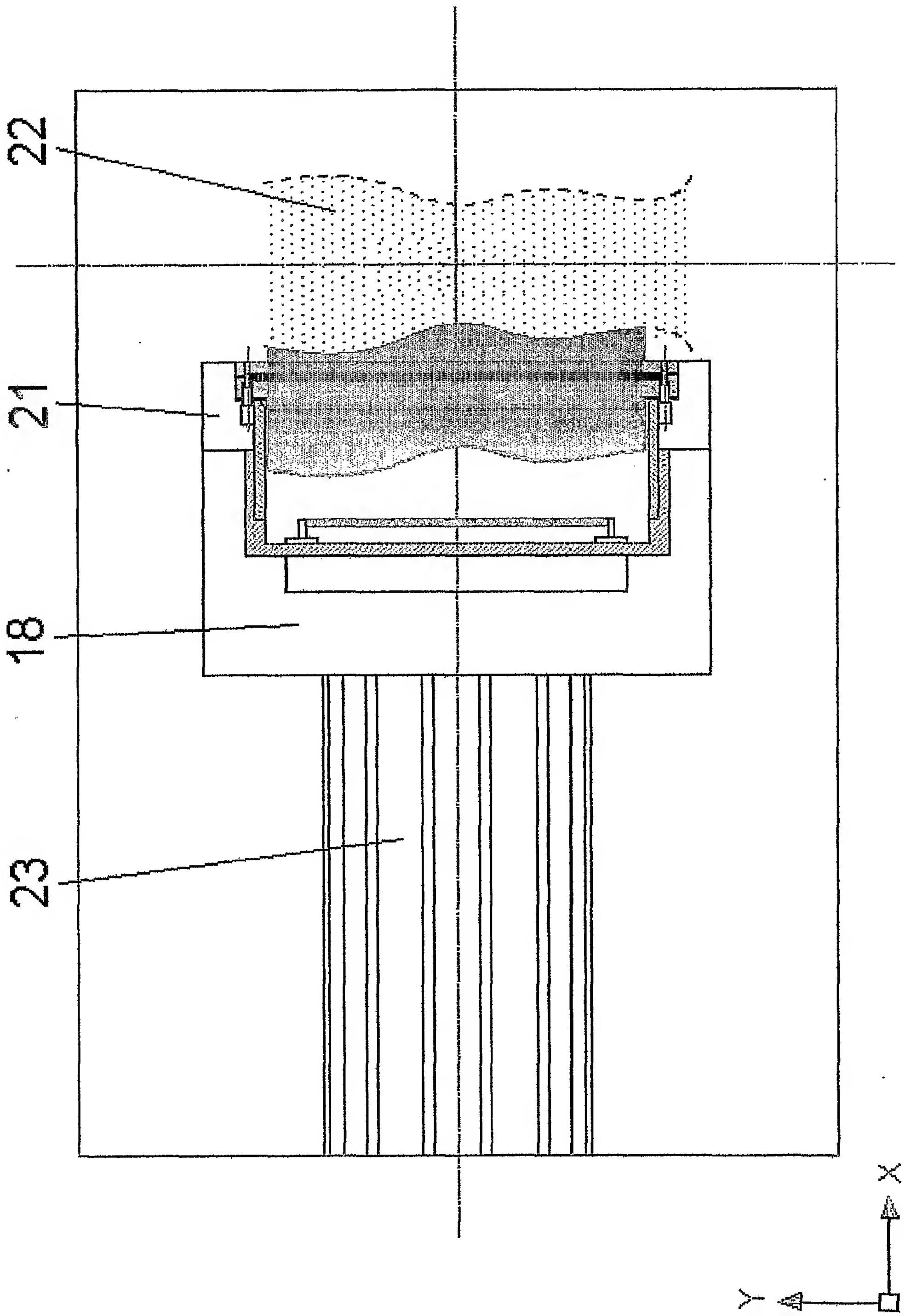

Fig. 9

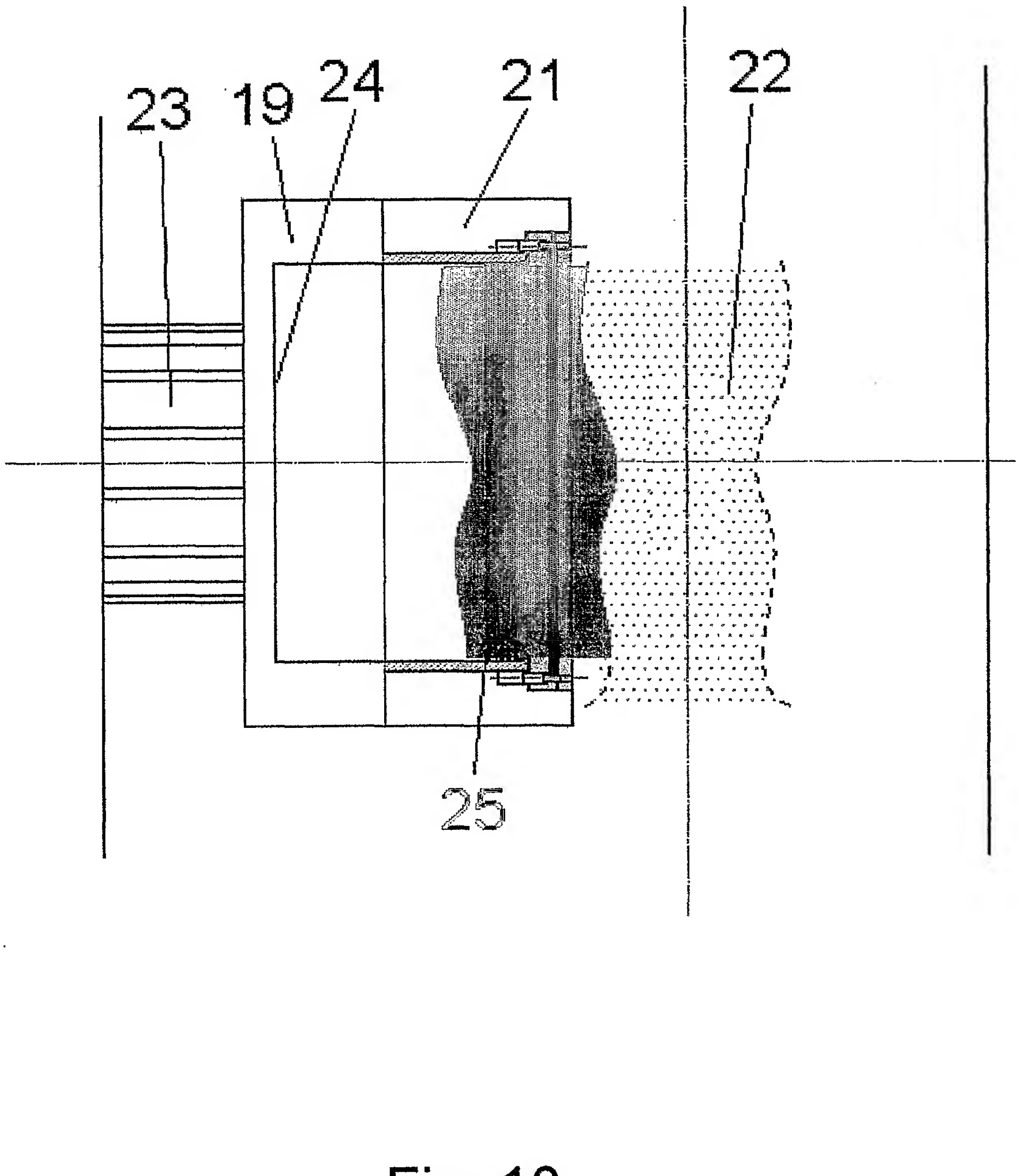

Fig. 10

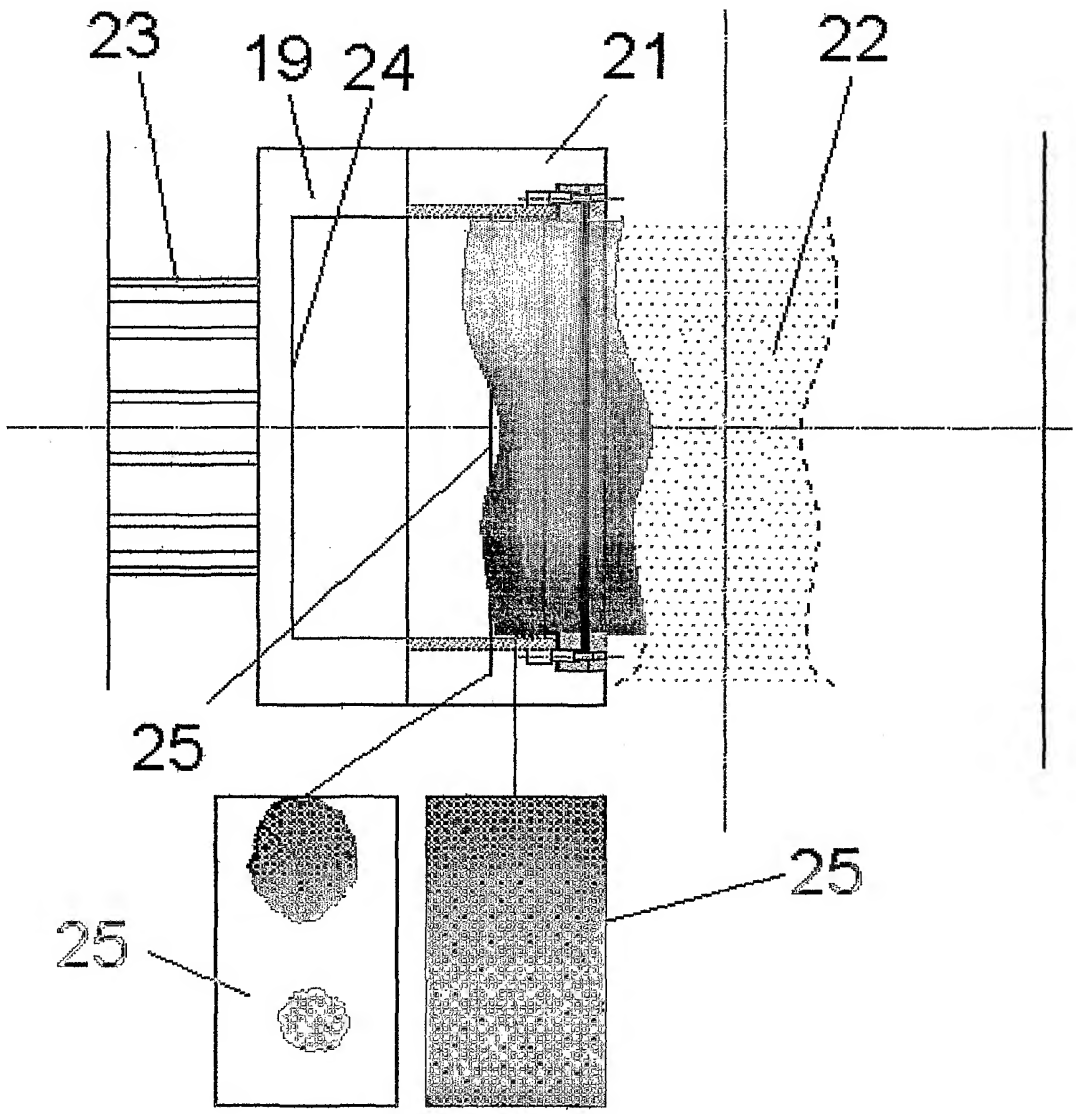

Fig. 11

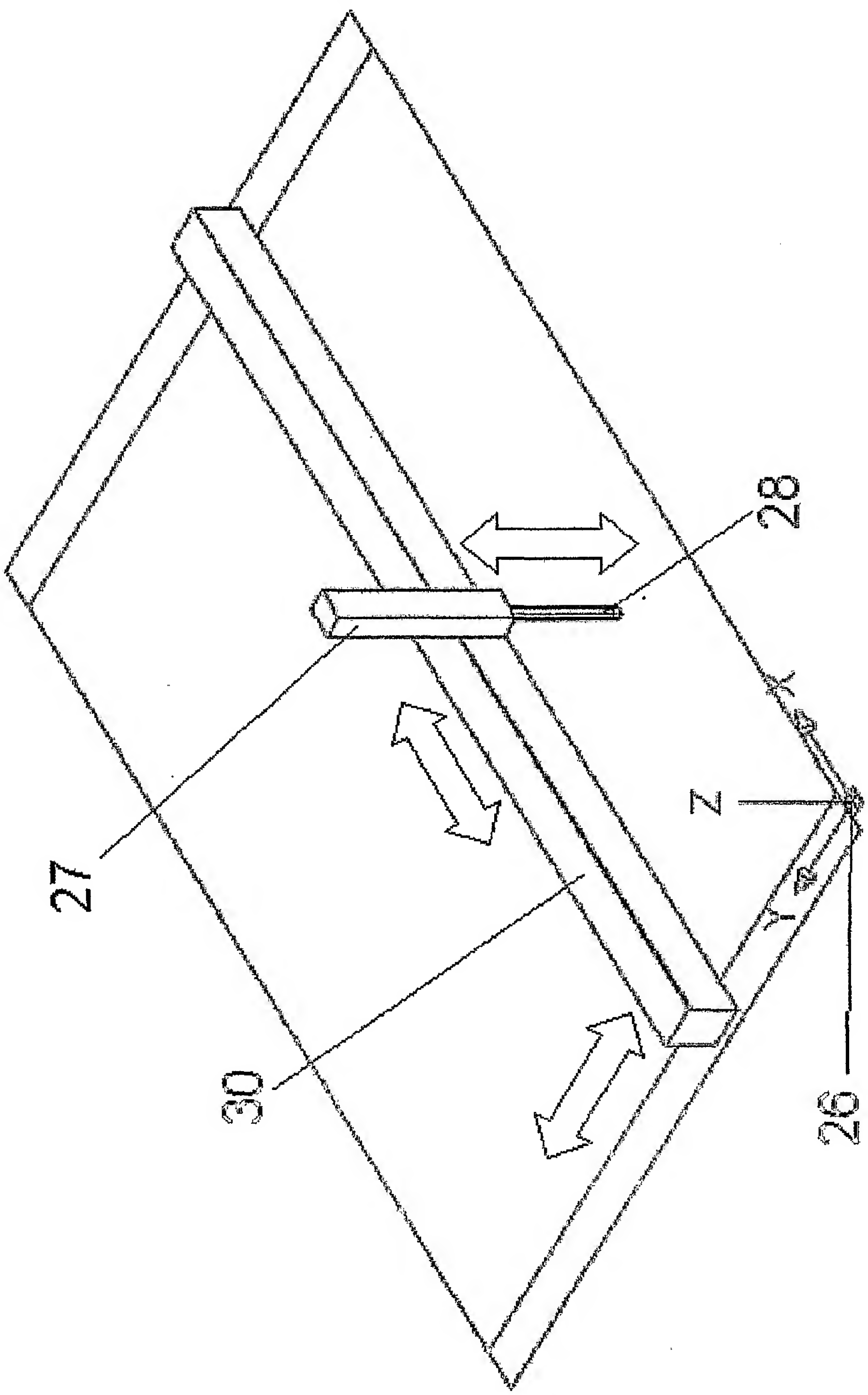

Fig. 12

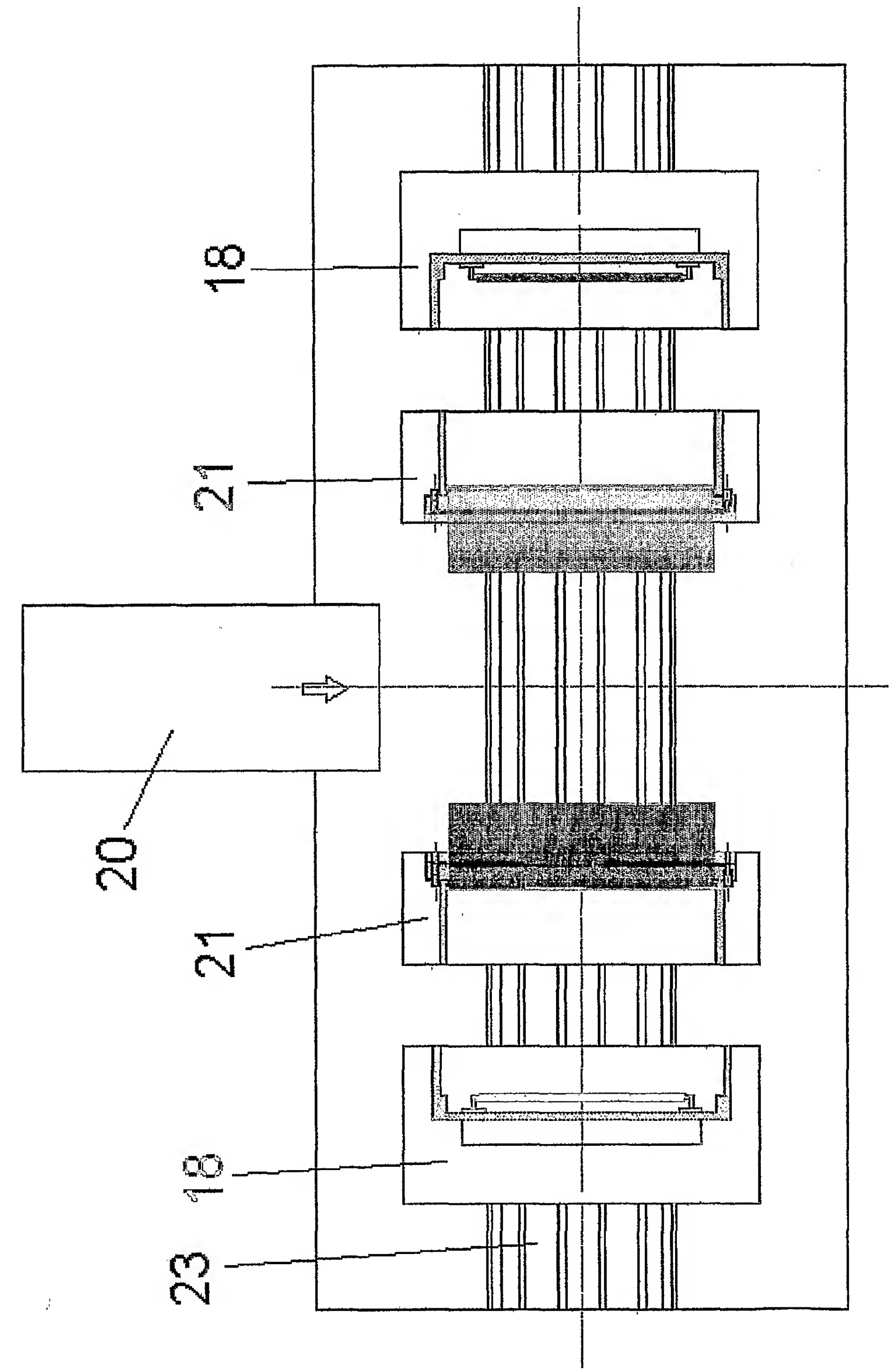

Fig. 13

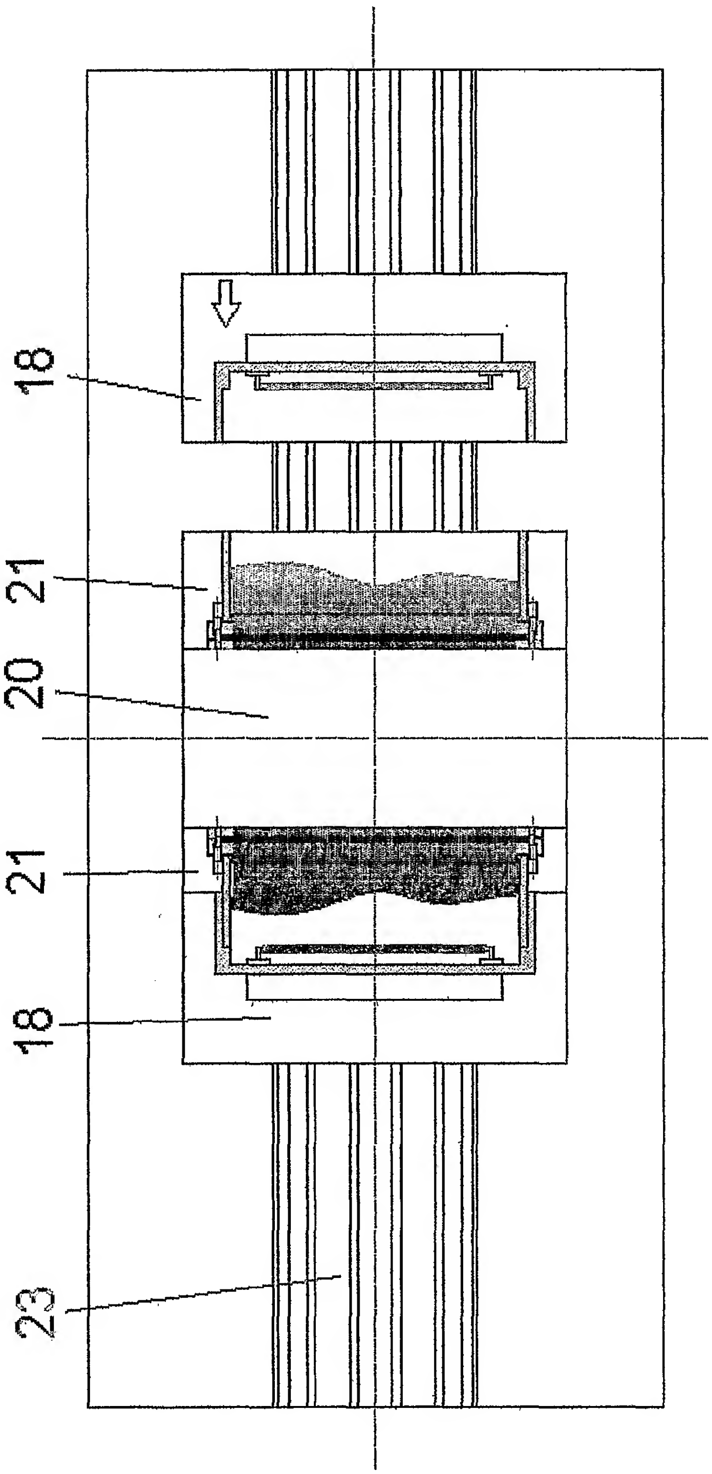

Fig. 14

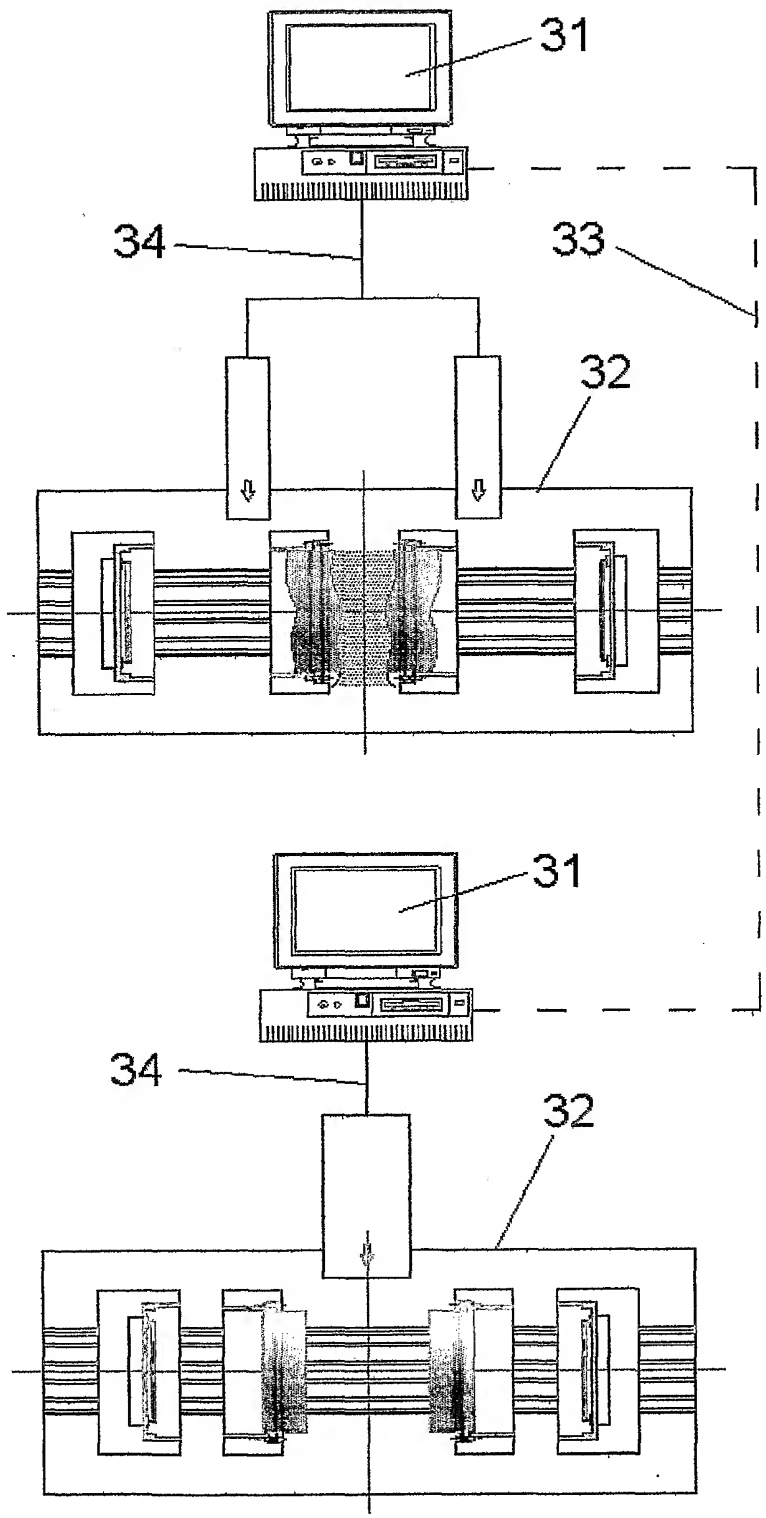

Fig. 15

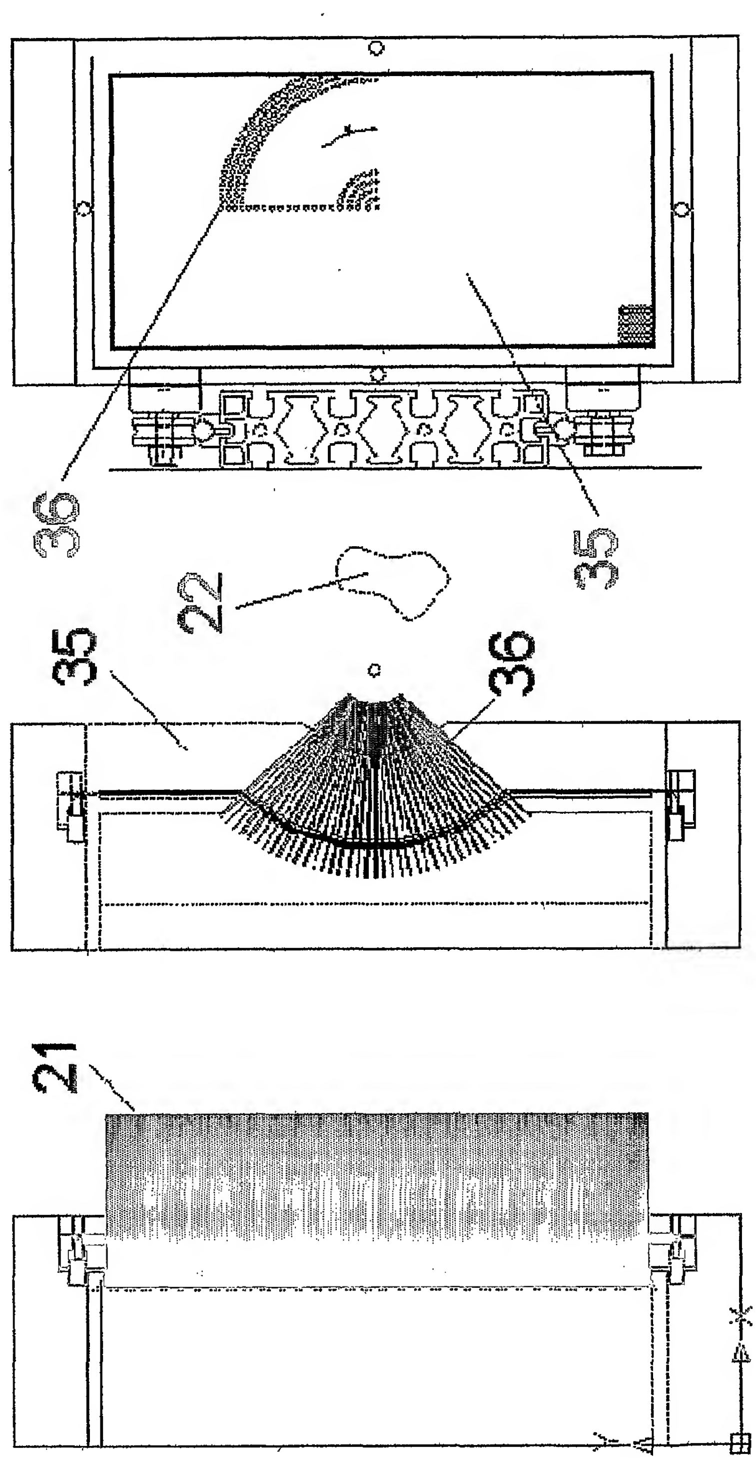

Fig. 16

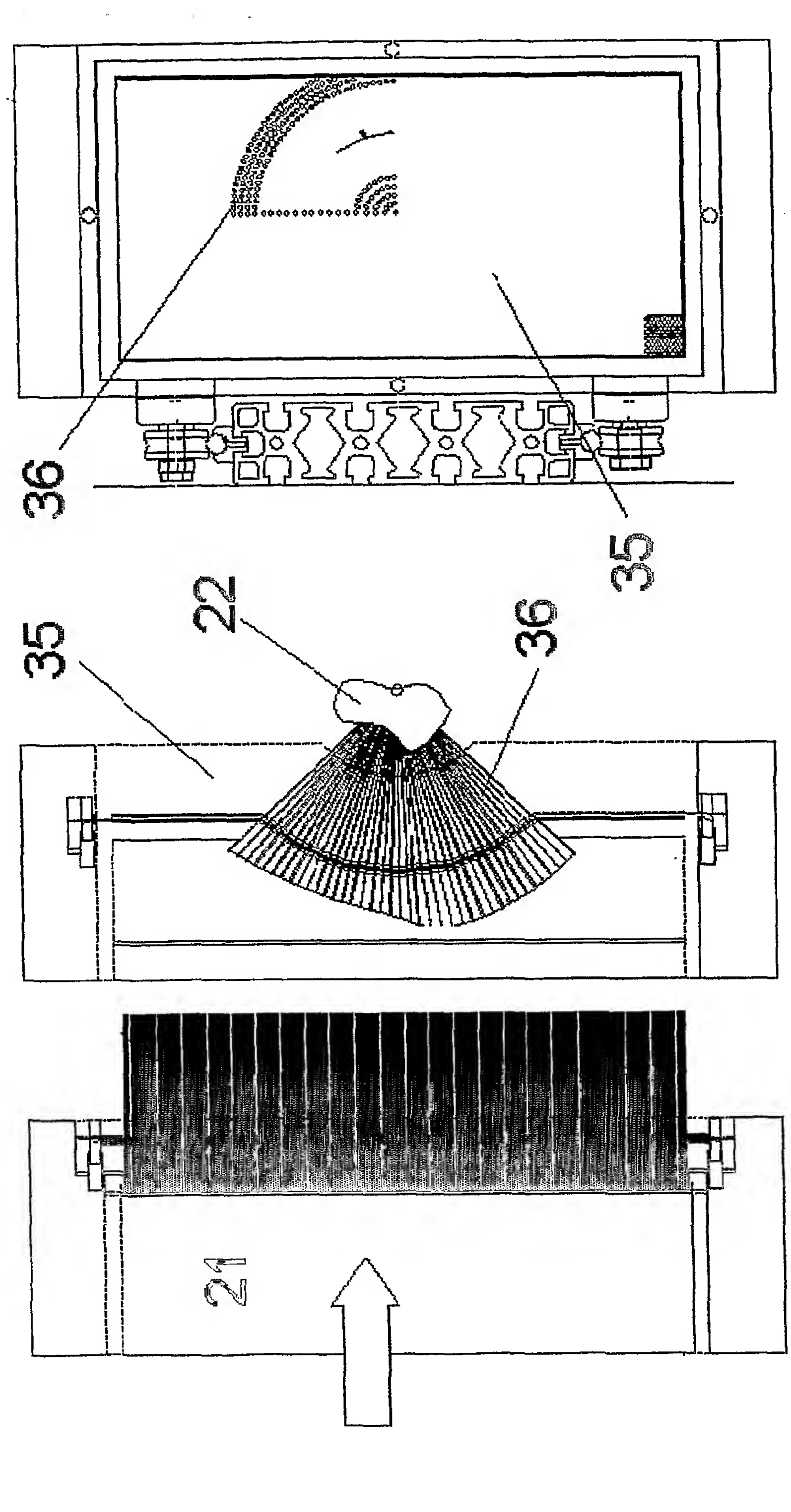

Fig. 17